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The effect of sound delivery methods on a user's sense of presence in a virtual environment

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NAVAL POSTGRADUATE SCHOOL
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THESIS

THE EFFECT OF SOUND DELIVERY METHODS ON A USER'S SENSE OF PRESENCE IN A VIRTUAL ENVIRONMENT

by

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March 2002

Thesis Advisor: Russell D. Shilling
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This thesis done in cooperation with the MOVES Institute.

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13. ABSTRACT *(maximum 200 words)*

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A computer based first-person shooter game (Medal of Honor: Allied Assault™) was utilized as the virtual environment. The independent variable was sound delivery method (no sound, 5.1 surround sound, headphones, and headphones with subwoofer). The dependent variables were physiological response and questionnaire results.

Results indicated that sound contributed to the user's sense of presence as evidenced by electrodermal activity and temperature and questionnaire scores. Also, significant changes occurred between the speaker and headphone sound delivery methods. This response suggests that speakers created a higher sense of emotion and possibly induced a higher level of presence in participants.

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I. INTRODUCTION

The United States military has been using virtual environments for many years. Examples include flight simulators for pilot training and conduct of fire trainers for tanks and armored vehicles. As resources dwindle, both monetarily and environmentally, the military has continued to look to technology to overcome the lack of resources for training.

The first virtual environment trainers were designed for mounted soldiers and airmen, those who operate vehicles such as tanks and aircraft. But with dwindling resources, the emphasis is shifting to simulation of all types of military operations including dismounted operations. These new virtual environments have the potential of allowing safer and less expensive training for the dismounted military [LAMP 94]. While technology such as virtual environments is not the panacea for all training, it does have its applications.

A motto in the military is “train like we fight, fight like we train”. Using real world exercises, it is easy to see how the motto is supported. However, when the training is done in a virtual environment, it may be difficult to adhere to the motto. In order for the military to “train like we fight” the soldier might benefit from “feeling” like he is in the environment. This is commonly referred to as presence or immersion. But until an objective measure of presence is discovered, it is hard to determine what effect presence has on training.

A. PRESENCE IN VIRTUAL ENVIRONMENTS

> One aspect of the subjective experience in VE systems that has received considerable attention is the extent to which the human operator loses his awareness of being present at the site of the interface and instead feels present in the artificial environment. This feature is often referred to under the headings of tele-presence, virtual presence, or synthetic presence and is dependant on many factors, including (but not limited to) the extent to which the interface is transparent and attenuates stimulation from the immediate environment, as well as the amounts and kinds of interaction that take place in the artificial environment [DURL 95].

The term “virtual environment” or “virtual reality” implies the user will experience an alternate reality in place of true reality. Within this context, the term “presence” has been used to describe the subjective state of “being there” in a mediated environment. The reason for the perception of being in the environment is both a product of the environment and the interface used to interact with that environment. Witmer and Singer consider presence and immersion inseparable entities [WITM 98]. Slater considers immersion a product of the hardware used in the virtual environment [SLAT 99]. The difficulty lies in measuring “presence”.

> A better understanding of what presence is, what encourages and discourages it in users, and its effects, should save valuable time and money and improve the end product in the design of new and redesign of current media technologies [LOMB 97].

Even though presence has not been adequately defined, it is generally believed that the greater number of human senses involved in a virtual environment, the greater the

possibility the VE has of generating presence [LAWS 98]. This line of thinking follows the real world. People are present in the real world and are inundated with stimuli that affect all of their senses. In order to achieve the same sense of presence in the real world, the virtual world should incorporate as many of the same senses as possible.

B. QUANTIFYING PRESENCE

Research in quantifying presence is still in its infancy. Various means have been used in an effort to quantify this phenomenon. Two categories of measurement methods (subjective and objective) have been used in an attempt to quantify presence. Due to the subjective nature of presence, it is most easily measured using subjective questionnaires. This method allows the user to subjectively rate how present they felt in the environment by answering a list of questions concerning their sense of presence while in the VE. However, there are inherent problems with subjective questionnaires. Some drawbacks include the respondent's understanding of presence, relying on memory to answer the questionnaire, and bias due to the appeal of the VE content. Other subjective means of measuring presence are continuous presence assessment and psychophysical methods. Objective corroborative measurement methods include collecting data on a user's postural changes during VE exposure, measuring the user's physiological responses during VE exposure, and administering a post-exposure test used to quantify where attentional resources were focused during exposure to a dual-task environment. All of these methods are discussed in greater detail in the background section.

C. RESEARCH OBJECTIVES

The first objective of this research is to determine how the method of sound delivery affects the user's sense of presence in a virtual environment. The motivation for this is the continuing dependence of the military on computer-based training aids. Headphone systems have a much smaller footprint than speaker systems, making them a desirable choice for deployable simulators. If it can be determined that headphone delivery is as effective as speakers in creating a high sense of presence, then military organizations will be able to minimize cost and space requirements for computer based training aids. Presence will be measured using both objective and subjective means.

Another goal is to investigate an objective method for measuring a user's sense of presence in a virtual environment. Current methods rely on subjective ratings that may vary widely between individuals as well as the same individual between rating periods. Objective measures remove some of this variability and may allow for a more reliable measurement of presence. The operational definition of presence for this study is change in physiological responses. The participant's physiological responses will be recorded while they are exposed to and interact with the virtual environment. These responses will give insight into the emotional state of the participant while in the virtual environment. The change in emotional state should also result in a change in the user's sense of presence (see figure 1). Additionally, the

responses will be compared to the participant's subjective level of presence as measured with a questionnaire to determine if a correlation exists.

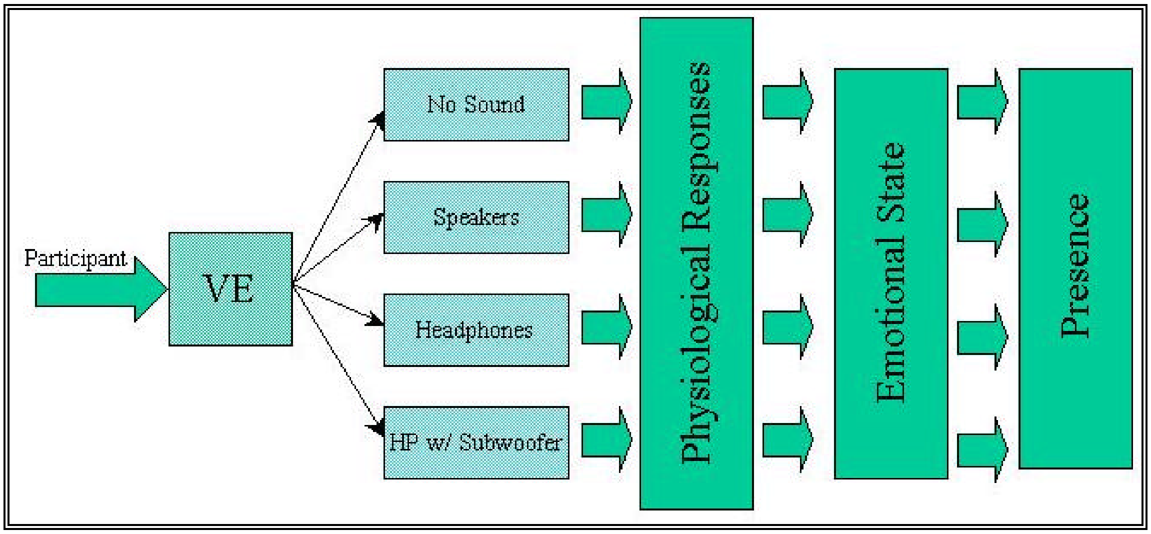

Figure 1. Theoretical Approach Linking Emotional State to Presence.

D. THESIS ORGANIZATION

This thesis is organized into the following chapters:

- Chapter I: Introduction. This chapter provides an overall outline of the thesis. It discusses the importance of presence in virtual environments and current measuring techniques. It also covers the research objectives and motivation behind this thesis.
- Chapter II: Background. This chapter covers past and present work relevant to this thesis. It defines presence and immersion, differences between the two, factors that influence presence, methods for measuring presence, and describes how physiological monitoring can be used to link subjective measures of presence (questionnaires) to objective measures of presence (physiological responses). It also discusses the background on emotions and the physiological correlates of emotion.

- Chapter III: Method: This chapter describes the experiment and the four treatments administered to the participants.
- Chapter IV: Analysis. This chapter contains the results of the experiment in terms of the stated hypotheses.
- Chapter V: Conclusions and Recommendations. This chapter provides an overview of the experiment, the conclusions, and recommends future work in this area of research.
- Appendices:
    A. Raw Data
    B. Experiment Protocol
    C. In-brief Script
    D. Consent Forms
    E. Questionnaires
    F. Equipment Specifications

II. BACKGROUND

A. VIRTUAL ENVIRONMENTS

Over the past couple of decades, virtual reality (VR) and virtual environments (VE) have become hot topics of discussion and experimentation. Virtual reality has enabled us to create many different virtual objects and environments. Virtual universities, offices, pets, actors, studios, museums, doctors, and wind tunnels are some of the many virtual creations, just to name a few. Virtual environments or synthetic environments create a **virtual reality** using **immersive** hardware devices designed to allow the user to navigate and interact with the environment in such a way that he actually feels **present** within the environment. In order to fully understand this definition, it is imperative that we understand how virtual reality, immersion, and presence relate to virtual environments.

To adequately define virtual reality, we must first understand the meanings of the words “virtual” and “reality”. *Virtual* is defined as existing or resulting in effect or essence though not in actual fact, form, or name. *Reality* is defined as the quality or state of actual or true [WEBS 88]. Combining these two definitions, virtual reality seems to suggest a reality that is believable (accepted as real or true), and yet does not physically exist.

John Vince describes two types of VRs, immersive and non-immersive. Immersive VRs were originally described as environments that provided the user with a “first person” view of the virtual world.

> In the 1980s real-time computer graphics became a reality, and VR became a commercial reality. Initially, early VR systems comprised a real-time computer system, a head-mounted display (HMD), and an interactive glove. Apart from supplying the user with stereoscopic images, the HMD immersed the user in the virtual world by preventing them from seeing the real world. Immersion increased the sensation of presence within the virtual world, and for some people, immersion distinguished VR systems from other types of real-time computer graphics systems [VINC 01].

Early computer games were considered non-immersive VRs. They did not provide the user with a real-time 3D environment in which to navigate or interact, and they did not provide a "first person" view of the virtual world. Today, an immersive VE can be achieved using a PC capable of displaying real-time images of 3D environments that provide a "first person" view and allow the user to navigate and interact with the mediated environment. Although computer simulations and "first person" type games can induce a sense of presence in their users, their immersive capabilities still fall well short of their more expensive partners (CAVES and fully interactive HMD environments). In order to fully understand what virtual reality is, discussion of its defining characteristics, **immersion** and **presence**, follows.

B. IMMERSION

Immersion, as defined by Vince, is the sensation of being part of a VE [VINC 01]. Slater defines immersion more specifically as a product of the VE hardware [SLAT 99]. There are many characteristics of VE hardware that

encourage this sensation and a non-exhaustive list of some of these characteristics and how they influence immersion is shown in table 1.

Table 1. Hardware Characteristics that Influence Immersion.

Immersive Characteristics	Affected Sense	Influence on Immersion
Field of View Stereoscopy Display Screen Resolution Color Display Refresh Rate Update Rate	Vision	Limits Real-World Distractions Increases Depth Perception Improves Image Quality Increases Scene Realism Improves Display Quality Reduces Flicker Distractions/Eye Strain
Sound Surround Sound	Hearing	Introduces Sense of Hearing Improves Sense of Location and Orientation (Spatialization)
Haptic/Tactile Feedback	Touch	Introduces the Sense of Touch Provides Force Feedback
Olfactory Feedback	Smell	Introduces the Sense of Smell
Kinesthetic Feedback	Vestibular	Provides a Natural Means for Self-Motion/Navigation in the VE

Lessiter claims “...the greater the number of sensory inputs provided to different modalities, the greater the sense of presence” [LESS 01]. This can be restated as the greater immersive characteristics of the environment and the more modalities presented within the VE, the greater the resulting sense of presence for the VE participant. The two senses that receive the most attention in VEs are vision and hearing. The sense of vision is relied upon about 70 percent of the time for perception in the real world, while hearing (sound) accounts for about 20 percent. The remaining ten percent is distributed among the other

sensing modalities [HEIL 92]. This being said, Tom Holman and the artists at Lucasfilm™ consider audio a primary emotion-inducing medium in movie presentation comprising at least 50% of the motion picture experience [HOLM 00]. The above table shows various immersive characteristics that can be adjusted to influence the immersive qualities of a VE. As the immersive qualities of a VE increase, the ability of the VE participant to feel like they are actually present in the environment also increases. This feeling of actually being present in a VE, known as "presence", is the next subject of discussion.

C. PRESENCE

> When the curtain swept up to reveal the now-legendary wide-screen roller coaster ride, I realized the film's creators were no longer content to have me look at the roller coaster but were trying to put me physically on the ride. The audience no longer surrounded the work of art; the work of art surrounded the audience – just as reality surrounds us. The spectator was invited to plunge into another world. We no longer needed the device of identifying with a character on the other side of the 'window.' We could step through it and be a part of the action! – Morton Heilig commenting on his experience with Cinerama in New York, 1952.

1. Definition of Presence

The most commonly stated definition of presence is a sense of "being there" in a mediated environment. The term implies that those who are using a virtual environment actually feel as if they are part of the virtual environment [KALA 00]. This in turn implies that the user will get as much sensory input from the virtual environment as he would from the real world. While current technology

cannot support the last statement fully, it is the ideal virtual environment.

Presence can be illustrated as a "continuum of reality". On this continuum, the left endpoint is zero or low presence (less realistic) while the right endpoint is high presence (more realistic, see figure 2). Consider the following environments and where they might go on the continuum: TV show, movie (in a theater), desktop VR, IMAX movie, CAVE application, and a Head Mounted Display (HMD) application. The TV show will go toward the low end of the continuum. While placement is arbitrary, TV shows do not offer much in the way of viewer involvement. Next, consider a movie shown in a movie theater. It offers a more compelling environment due to soundtrack delivery over a high quality speaker system and will most likely induce a higher level of presence than the TV show. Therefore, it will appear to the right of the TV show on the reality continuum. Thirdly, a desktop VR application allows for user interaction, thereby possibly increasing presence. It will go to the right of the movie. An IMAX™ movie, on the other hand, will go to the right of the desktop VR due to its ability to involve the viewer with a wider field of view. Virtual environments that involve a CAVE or a HMD go even further to the right. The CAVE is to the left of the HMD due to the HMDs ability to completely block any external visual stimuli from the user. The CAVE still allows the user to see the floor, back wall, or any other part of the apparatus that is not part of the display.

Another aspect of these "environments" that needs to be considered is the content of the environment. A black

and white or silent movie will most likely rank lower in presence than the new “high-tech” movies of today (e.g. Star Wars, Terminator, etc.). While there is some room for argument on what goes where on the continuum, these are just examples to illustrate the concept. There are no hard and fast rules on placement of environments on the continuum primarily due to the lack of a solid definition of presence.

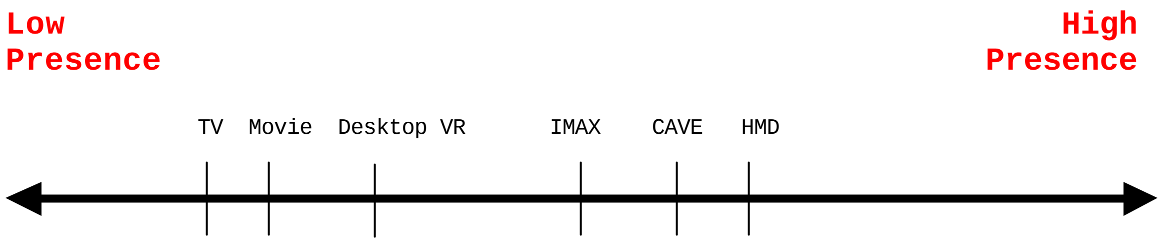

Figure 2. Continuum of Reality.

A number of variables appear as possible causes of presence, either positively or negatively, and is shown in table 2.

Table 2. Possible Causes of Presence (From: [KALA 00]).

Variable	Contribution
Form Variables – This group includes the more objective parameters	
Sensory outputs	
Number of sensory outputs	Positive (for higher numbers)
Consistency of sensory outputs	Positive (when consistent)
Visual outputs – have various dimensions	Strong – see dimensions below
Display size	Positive (for larger proportion)
Viewing distance	Positive (for larger proportion)
Quality of image	Positive (for high quality)
Depth cues	Positive
Camera techniques	Positive
Audible outputs – has different dimensions	Strong
Other sensory outputs (smells, touch etc.)	Can be influential, but usually less strong than audio or visual
Body movement and force feedback	Positive when done well
Inactivity of medium	Positive
Visibility/obtrusiveness of medium	Negative
Interference from real world	Negative
Human contact	Positive
Content variables – can be objective and subjective	
Characters and storylines	Positive and negative
Media conventions	Usually negative
Nature of representation	Positive and negative
Media user variables – These are highly subjective and depend directly on the individual	
Willingness to suspend disbelief	Positive
Previous experience	Positive or negative

Although there exist many definitions of presence, Heeter has defined presence as having three dimensions: personal, social, and environmental [HEET 92].

a. Personal Presence

Personal presence refers to the extent individuals feel they are present when operating in a virtual environment. Research in this area attempts to identify what features are needed in a virtual environment to convince users they are in another world [BERN 99]. The reasons that users may feel like they are in the virtual world are many but could be as simple as seeing their own hand in the virtual world.

b. Social Presence

Social presence is the extent to which other beings also exist in a virtual environment and react to the primary user. The premise is that if other people exist in the virtual world, it lends more credence that the world exists. The people can either be other humans interacting with the virtual environment or computer generated beings that are a part of the environment. In either case, the perception that someone recognizes the user in the VE creates a more believable environment for the user.

c. Environmental Presence

Environmental presence is the extent to which the environment reacts to the user. The ability to modify an environment has been proposed as a key component of presence [SHER 92]. Modification of an environment can be as simple as moving a chair or turning on a light with a light switch. Environmental presence is also enhanced when the objects in the VE behave similar to their real world

counterparts. If the user has the ability to do something in the VE that cannot be done in the real world (i.e., walk through objects like walls or furniture), their sense of presence may be adversely affected.

2. Measuring Presence

Research in presence measurement is still relatively young. Currently, there is no generally accepted theory on presence [IJSS 00]. In an effort to quantify the user's sense of presence, most measuring techniques contain a means for collecting data on a combination of all three dimensions explained above. Because of this, many methods have been utilized. The different methods can be divided into two categories: subjective measures and objective corroborative measures. The following sections discuss the more common methods used in each category.

a. Subjective Measures

The subjective nature of presence has led to the argument that the "subjective report is the essential basic measurement" for obtaining a user's level of presence [SHER 92]. The most common subjective measure is through post-test rating scales. Other methods include continuous presence assessment and psychophysical methods. The lack of an exact definition of presence makes creating one standard subjective means for gathering data nearly impossible.

(1) Questionnaires: Questionnaires are by far the easiest method available for measuring presence. An advantage of questionnaires is the unobtrusive way in which they can be administered. There are several subjective questionnaires designed to obtain an individual's sense of presence [SLAT 98, SING 96, LESS 00].

Although most questionnaire authors possess similar views on presence, the lack of a standard operational definition for presence allows different interpretations on how to quantify this phenomenon.

Slater’s definition of presence includes three aspects: (i) the sense of being in the mediated environment, (ii) the extent users respond to events in the VE vice the real world, and (iii) the extent that user’s remember the VE as a place they visited rather than something that was seen on the computer [SLAT 99]. Slater further defines immersion as the extent the VE hardware delivers a surrounding environment, shutting out real world sensations and replacing them with virtual world sensations.

Witmer and Singer, on the other hand, consider presence a product of involvement and immersion. Immersion, according to Witmer and Singer, is a psychological state characterized by the perception of being enveloped by, included in, and interacting with an environment that feeds the user a continuous stream of stimuli [WITM 98]. It is this difference of opinion that separates Slater’s questionnaire from Witmer and Singer’s.

Slater takes issue with Witmer and Singer’s questionnaire because some of their questions address hardware issues that he believes is a factor of immersion not presence. Ijsslesteijn, de Ridder, Freeman, & Avons [IJSS 00] also note a problem in Witmer and Singer’s questionnaire is the inseparability of individual characteristics and properties of the virtual environment caused by their definition of immersion. Various other questionnaires have been developed and are being used in an

effort to gauge an individual’s level of presence when placed in a mediated environment, but limited consolidated data is available on these questionnaires.

(2) Continuous assessment: An obvious criticism of post-test ratings is the lack of rating presence as a variation in time. The result of questionnaires is the overall sense of presence experienced by the user throughout the time spent in the virtual environment. In order to overcome this shortfall, attempts have been made to measure presence on a more continuous scale. This method requires the user to make a presence judgment during use of the environment by adjusting a slider that is continuously sampled by the computer (see figure 3) [IJSS 00].

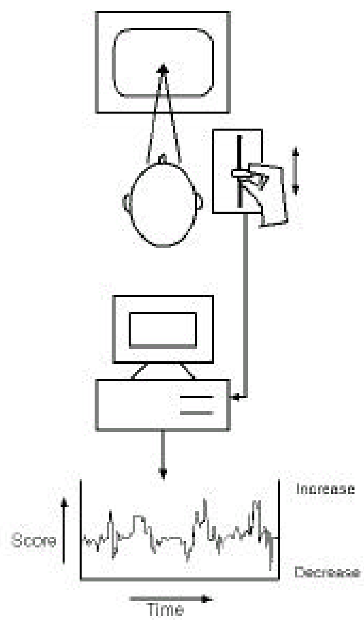

Figure 3. Continuous Assessment Schematic (From: [IJSS 00])

Continuous assessment has one glaring potential criticism: how does adjusting the slider affect a user’s

sense of presence? The user has to continuously make "presence" judgments during use of the virtual environment to adjust the slider thereby potentially disrupting the whole experience. However, this may not be the case since most users of a virtual environment know that they are actually in a lab using a virtual environment and reporting on a sensation of being in the virtual environment. This is common to both continuous assessment and questionnaires [IJSS 00].

(3) Psychophysical Methods: Some psychophysical methods have been proposed, but not much research has been done. Psychophysical methods include free-modulus magnitude estimation, cross-modality matching, and paired comparisons.

Snow and Williges used free-modulus magnitude estimation to investigate the effects of a wide variety of parameters on presence [SNOW 98]. Free-modulus magnitude estimation involves the presentation of several stimuli to a participant. The participant is required to assign a number for each stimulus based on the strength of their subjective sensation. The first stimulus presented is almost arbitrary, but the following stimuli are based off the first.

The second psychophysical method is cross-modality matching. It is a variation of magnitude estimation but is usually reserved for those situations where verbal scaling is difficult. Cross-modality matching requires the participant to indicate his level of presence in one modality by expressing adjustment of a parameter in another modality (e.g. "Make this sound as intense as the strength of presence you experienced in this VE") [IJSS 00].

The final psychophysical method to discuss is paired comparisons. Within the context of virtual environments, this has sometimes been referred to as the “virtual reality Turing test” [IJSS 00]. In this method, a participant is asked to distinguish a real scene from a virtual one. Obviously, it will be unlikely that the participant will not be able to determine which the real scene is. In order to give each scene an “equal footing”, both scenes have to be viewed under the same constraints, i.e. limited field of view, no sound, reduced color/contrast, etc. The amount of degradation of the real scene required to make it indistinguishable from the virtual scene is the measure of presence. A criticism of this method is that it is not a measure of presence but rather a measure of the participant’s ability to discriminate between two bad images [IJSS 00].

b. Objective Corroborative Measures

One of the downsides of using subjective measures of presence is that they require the respondent to have an idea of what is meant by presence. Most users are unfamiliar with the term presence as it applies to virtual environments. Also, if a participant has an interest in the subject being displayed in the environment, his presence score may be biased (see [FREE 99]). It is these reasons that an objective measure of presence is sought. There are three main objective corroborative measures in use: postural responses, dual task measures, and physiological responses.

(1) Postural Responses: Postural responses are a measure of the participant’s observed body adjustments during virtual environment use. The idea is

simple: if the display better approximates the real world, the participant will react as if he is in the real world. This method bypasses the subjective measures by measuring responses that are automatic and not deliberately controlled [IJSS 00a]. In a study where participants were asked to stand as still as possible while watching a video of a rally car circling a track, it was found that postural responses cannot be substituted for subjective measures of presence since the two measures did not correlate across participants. However, postural responses can be used for corroboration of group subjective presence ratings [IJSS 00a]. Something similar to postural responses is behavioural response. These include such automatic actions as ducking or flinching. The premise behind behavioural responses is similar to that of postural responses. That is, if the user responds to the virtual environment as he would in the real world, then a higher sense of presence is experienced.

(2) Dual Task Measures: Dual task measures are consistent with the view that attention allocation is an important part of presence. Because of this, another objective method is that of secondary reaction time measurements. As more attention is focused on the primary task, less attention remains for the secondary task. This typically results in participants making more errors or taking longer to respond to the secondary task [IJSS 00]. Darken, Bernatovich, Lawson, and Peterson conducted a study comparing the roles of attention and spatial comprehension on presence. They concluded that attention might be a reasonable objective measure of presence but found no

correlation between spatial comprehension and presence [DARK 99].

(3) Physiological Measures: Physiological measures, such as heart rate and skin conductance, have been suggested as objective corroborative measures of presence. However, little research has been done to relate physiological measures to presence [IJSS 00]. In order to discuss how physiological responses are related to presence, it is necessary to identify the relationship between the body's physiological responses, emotions, and presence. The next section discusses previous research in determining this relationship and the following section discusses the theory behind emotions and how they relate to physiological responses.

c. Previous Research in Measuring Presence

Although research in the measurement of presence is in its infancy, several attempts have been made to establish a reliable repeatable measure for this phenomenon. The following table lists several research attempts, identifies the independent and dependent variables, lists methods of measurement used during these attempts, and the results from these efforts.

Table 3. Presence Related Research.

Researchers	Independent Variable	Dependent Variable	Method of Measurement	Results
[DETE 98]	Motion – Video vs Still Pictures	Emotional Reactions	Self-Reports (SR) Phys Data (EDA & HR)	Motion increased arousal (EDA & SR) and caused HR deceleration
[IJSS 00]	Motion – Video vs still pictures Display – Mono vs Stereo	Postural Responses (PR), Presence (P), Vection (V), Involvement (I), and Motion Sickness (MS)	Magnetic Tracker Subjective Ratings	PR – No significant Response (NSR) Motion Increased P, V, & I; NSR for MS Display Increased P
[DINH 98]	Display – Low vs High Fidelity Audio – On vs Off Olfactory – On vs Off Tactile – On vs Off	Presence (P) Memory (M)	Overall P rating Subjective P questionnaire Quiz on Spatial Layout (SL) and Object Location (OL)	Display had no effect on P or M Audio increased P and SL M but had no effect on OL M Olfactory slight increase in P (Not Significant), increased OL M Tactile increase in P and OL M but no effect on SL M
[SLAT 95]	Locomotion – walk in place or pointed via mouse	Presence (P) Nausea (N) Association with the Virtual Body (VB)	Self- Assessment Questionnaires	Walking - correlation between higher association with the VB and higher sense of P Pointing – resulted in no correlation Higher degree of N associated w/ higher sense of P
[LESS 01]	Speaker Configuration EXP 1 – 1.0, 2.0, 5.1 EXP 2 – 2.0, 2.1, 5.0, 5.1	Presence (P) Audio-Visual (AV) Quality	Questionnaires	EXP 1 – 5.1 increased P & AV EXP 2 – Inclusion of Bass increased P & AV; number of channels had no effect
[FREE 01]	Speaker Configuration 2.0, 2.1, 2.0(Control), 5.0, 5.1	Presence (P) Audio-Visual (AV) Quality	Questionnaires	Inclusion of Bass increased P & AV; number of channels had no effect
[SLAT 98]	Body Movement Task Complexity	Presence (P)	Questionnaire	Increased movement increased sense of P Task complexity – No Signif. Effect

Table 3. Presence Related Research(cont).

Researchers	Independent Variable	Dependent Variable	Method of Measurement	Results
[FREE 99]	Motion – Observer Motion, Scene Motion, Minimal Motion Display – Mono vs Stereo	Presence (P) Interest (I)	Continuous Assessment	EXP 1 – Motion and Display increased P EXP 2 – No correlation between I and P; prior experience in the VE affected P EXP 3 – Prior experience affects P; Stereo Display increases P
[MEEH 00]	# of VE Exposures	Presence (P)	Questionnaire Behavioral Responses (questionnaires and video monitoring) Physiological Monitoring (EDA, HR, & Temp)	Correlation between EDA & P Repeated exposure decreases P
[DARK 99]	EXP 1 – Audio & Display EXP 2 – Audio	Presence (P) EXP 1 – Attention (A) EXP 2 – Spatial Comprehension (SC)	Questionnaire Attention quiz Spatial Comprehension quiz	EXP 1 – Audio increases engagement; A can be used as a partial measure of P EXP 2 – Audio increases P; no correlation between SC & P

The research efforts depicted in the table above show that, although much effort in establishing a clear measurement criterion for presence has been made, few concrete links have been established between dependent variables and presence. Additional research must be accomplished to identify the variables that most greatly affect an individual's sense of presence.

3. Emotions

> ...when the mind is strongly excited, we might expect that it would instantly affect in a direct manner the heart...when the heart is affected it reacts on the brain; and the state of brain again

> reacts through the pneumo-gastric nerve on the heart; so that under any excitement there will be much mutual action and reaction between these, the two most important organs of the body [DARW 72].

Merriam-Webster defines emotion as (1) the affective aspect of consciousness; (2) a state of feeling; (3) a psychic and physical reaction (as anger or fear) subjectively experienced as strong feeling and physiologically involving changes that prepare the body for immediate vigorous action [WEBS 88a]. The earliest and most influential theory of emotion is the James-Lange theory. This classic theory in psychology originated in the 1880s independently by William James, an American psychologist, and C. G. Lange, a Danish physiologist. James expressed his theory as follows:

> Common sense says, we lose our fortune, are sorry and weep; we meet a bear, are frightened and run; we are insulted by a rival, are angry and strike. The hypothesis here to be defended says that this order of sequence is incorrect,... that the more rational statement is that we feel sorry because we cry, angry because we strike, afraid because we tremble [JAME 90].

The shortened version of his statement is that humans feel emotional because we sense our body reacting. Bodily reactions and the perception of those reactions are factors in the experience of the emotion [GRIN 78]. The flip side is that without bodily reactions there would be no emotions.

A critic of the James-Lange theory was Walter Cannon. In a critical analysis of the relevant research in the early 1900s, he suggested five major areas of objection to

the James-Lange theory [GROS 67]. Central to his criticism of the theory were the following points [GRIN 78]:

1. When the bodily reactions that typically occur in emotion are prevented from occurring (as with transection of the spinal cord and vagus nerve, and removal of the sympathetic nervous system) emotional behavior in animals is not visibly altered.
2. The same bodily reactions occur in all emotions; hence these changes cannot produce qualitatively different emotions.
3. The viscera have fewer sensory nerves than other structures; hence people are typically unaware of the physiological processes occurring there.
4. Bodily reactions have relatively long latency periods, whereas reaction time for emotional responses is often much shorter.
5. Drugs, like adrenalin, that produce bodily reactions do not necessarily produce emotional reactions.

It is these criticisms that led Cannon to develop his own theory of emotions, known as the Cannon-Bard theory. His theory emphasized the role of sub-cortical structures, such as the thalamus and hypothalamus, in emotions [GRIN 78].

We cannot throw out the James-Lange theory altogether. Hohmann reported evidence that showed the James-Lange theory to be relevant. In a study conducted with patients who had spinal cord lesions, the James-Lange theory states the patients would have reduced emotional experiences due to the reduced number of messages from the viscera (glands and organs) to the brain. Cannon's theory states such lesions would have no effect on the patients' emotions. Cannon based his statement on a study conducted on dogs with such lesions, of which he said they responded

emotionally. He did point out that he could not tell if the dogs still felt emotion. The human patients in the study reported feeling less emotion after the lesion than before, but still maintained the ability to experience emotion [HOHM 66].

The effect of strain on the body is also an important consideration. Strain is the term used to describe the impact of stress on the body. The three categories of strain are physical, mental, and emotional. Physical strain is the actual physical load on the body, i.e. lifting a heavy item. Mental strain is the mental effort required by a particular task. Emotional strain is the excess mental effort required due to anxiety evoking concepts of the task, e.g. worrying about deadlines [BACK 00]. Each of these different strains affects the body in different manners. Table 4 indicates how the different strains have been shown to affect the physiological measure. The bolded measures are the more common ones used in objective corroborative experiments for measuring presence.

Table 4. Psychophysiological Parameters of Different Categories of Strain (From: [BACK 00]).

	Category of Strain		
Physiological Measure	**Physical**	**Mental**	**Emotional**
EEG alpha activity (8-12 Hz)		↓↓	
EEG theta activity (4-7 Hz)		↑↑	
P3 amplitude		↑↑	
P3 latency		↑	
CNV amplitude		↑	
Heart rate	↑↑	↑	↑
0.1 Hz component		↓↓	
Respiratory sinus arrhythmia		↓↓	
Additional heart rate		↑	
Respiration rate	↑	↑	
Finger pulse volume amplitude		↓	↓
Systolic blood pressure	↑↑	↑	
Diastolic blood pressure	↑	↑	
EDR amplitude		↑	↑
EDR recovery time		↑	
Spontaneous EDR frequency		↑	↑↑
Eye blink rate		↑↑	↑
Saccadic eye movements		↑	
Pupillary diameter		↑	↑
Electromyogram	↑	↑	↑
Muscle tremor	↑↑		
Core temperature	↑↑		
Finger temperature			↑
Epinephrine		↑↑	↑
Norepinephrine	↑↑		↑
Cortisol		↑	↑↑

Note: The variables are grouped according to their respective physiological stems. "↑" means that the values of the parameter in question increase with increasing strain, and "↓" that they decrease. More evidence is provided for double arrow than for single ones.

Depending on the situation, the body responds in different manners. This is the basis for the Three-Arousal model shown in figure 4. Arousal System 1 is labeled the affect arousal system and is responsible for focusing attention and orienting responses. Arousal System 2, the effort system, has the ability to connect or disconnect input and output. Arousal System 3, activation, results in

increased readiness of motor brain areas and is labeled the preparatory activation system. Affect arousal shows up in phasic heart rate or EDR amplitude. The effort system can disconnect systems one and three to prevent immediate action and allow time for analysis [BACK 00].

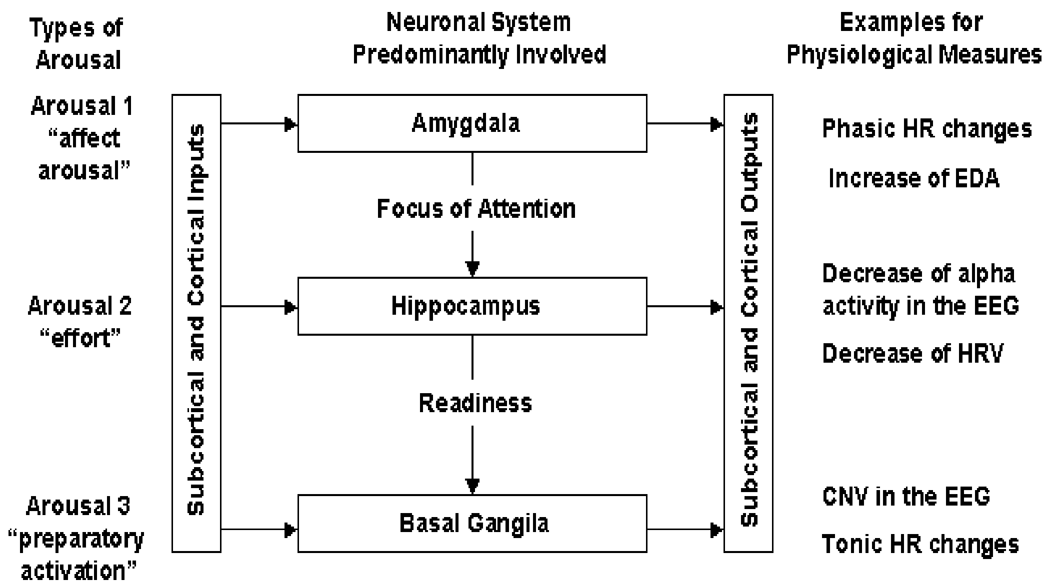

Figure 4. Three Arousal Model for Engineering Psychophysiology (From: [BACK 00]).

The study of emotion has taken four general paths: emotional experience, emotional arousal, emotional action, and emotional stimulation. Emotional experience refers to the subjective reporting of states felt and inferred. Emotional arousal deals with changes within the body brought on by external stimuli. Emotional actions are the direct response patterns (e.g., attack, smile, etc.). Finally, emotional stimulation refers to the features of the environment that illicit one or more of the above [BLAC 70].

a. *Physiological Correlates of Emotion*

Many physiological changes can occur during changes in emotional states. The body controls its physiological state through the nervous system. This system has two branches: the central nervous system (CNS) and the peripheral nervous system. The CNS includes the brain and spinal cord while the peripheral system refers to the nervous tissue external to the brain and spinal cord. The peripheral system is further divided into the somatic nervous system and the autonomic nervous system (ANS). The somatic system is concerned with muscular activities while the ANS controls the body's visceral structures. The ANS is further divided into the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS)[GRIN 78]. The SNS is dominant in situations requiring the mobilization of energy while the PNS is dominant when the body is at rest [ANDR 80]. Table 5 illustrates which portion of the nervous system controls different physiological responses. See figure 5 for a schematic of the nervous system and its major branches.

Table 5. Nervous System Mechanisms in the Control of Physiological Responses (From: [ANDR 80]).

Central Nervous System	**Somatic System**	**Autonomic Nervous System**
EEG (ongoing activity) Event-related potentials	EMG EOG	Heart rate (PNS, SNS) Blood pressure (PNS, SNS) EDA (SNS only) Pupil response (PNS, SNS) Blood volume (PNS, SNS)

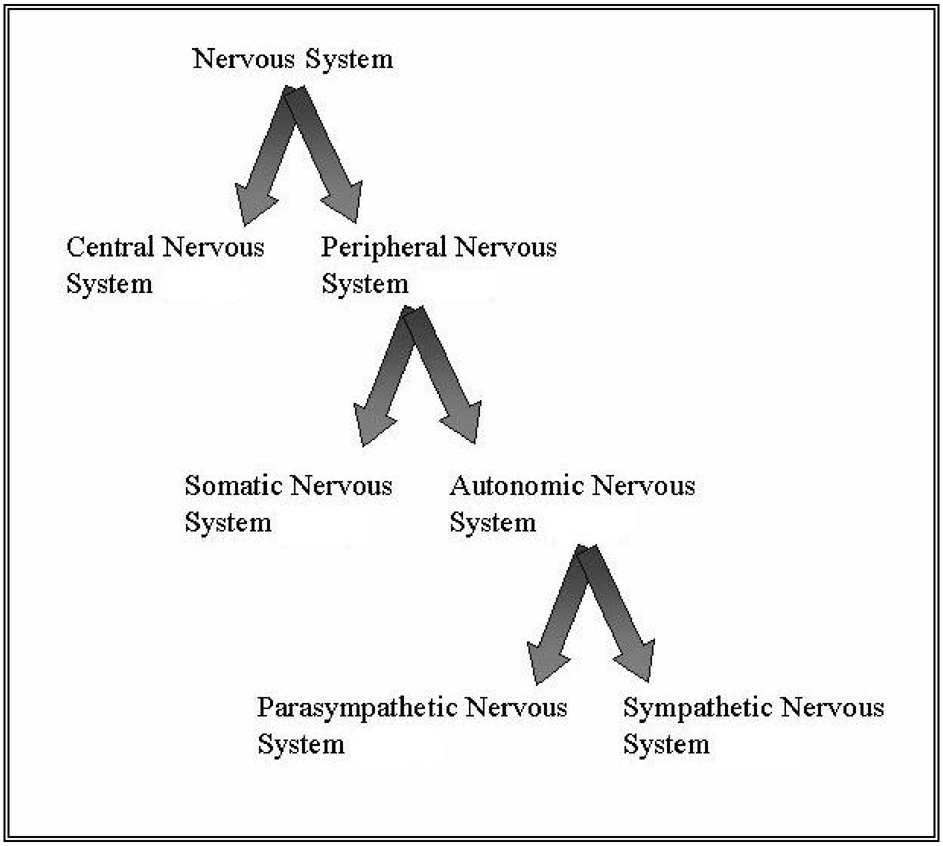

Figure 5. Schematic Drawing of Nervous System Showing the Major Divisions (From: [ANDR 80]).

The body has many reactions that accompany emotions. The six primary responses are heart rate, blood pressure, blood volume, electrodermal response, muscle potentials, and electroencephalogram and related measures [GRIN 78]. These measures can be recorded any number of ways and in any combination.

Heart rate is one of the most frequently measured responses and is the most common measure of heart activity. It is usually expressed in beats per minute (bpm). The normal rate for an adult human heart averages around 70bpm, although this can fluctuate from below 50bpm to over 100bpm as a result of emotions or other factors [GRIN 78]. The

beat represents the contracting of the heart in order to pump blood to the rest of the body. This beating is controlled by both internal and external mechanisms. Internal mechanisms consist of a system of specialized fibers. External factors, such as the nerves of the ANS and CNS, also affect the rate at which the heart beats [ANDR 80]. Measurement of heart rate is typically accomplished by an electrocardiogram (EKG or ECG). The EKG measures electrical potentials generated by the heart muscle [GROS 67]. There are several standard methods of attaching electrodes to record EKG and are described as follows [ANDR 80]:

> Lead I – Attach electrodes just above the wrist on both the left and right arms with the positive lead on the left arm.
>
> Lead II – Attach electrodes above the right wrist and left ankle with the ankle lead positive.
>
> Lead III – Attach electrodes above the left wrist and left ankle with the ankle lead positive.

The lead placements described above are adequate for measurement situations where movement is minimized such as sitting, lying down, or standing in one place. If movement of the participant is required, sternal or axillary leads are preferred. Sternal leads are placed over bones to minimize movement artifacts. Axillary leads are placed on the muscle under the arm but are not as free from movement artifacts as sternal leads [ANDR 80].

Heart rate indicates physical as well as mental load. The different changes in heart rate have different meanings. Tonic changes indicate the need to resupply

energy in preparation for response while phasic changes can be used to determine stimulus-directed processing activity. A decrease in finger volume pulse is a very sensitive measure of defensiveness and indicates both mental and emotional strain [BACK 00].

Blood pressure is the force exerted by the blood on the walls of the arteries. Pressure increases as the heart contracts and decreases as the heart relaxes. The maximum pressure that occurs when the heart contracts is called the systolic blood pressure. The opposite, the minimum pressure that occurs when the heart relaxes, is the diastolic blood pressure. The difference between these two is called the pulse pressure [GRIN 78]. The most common method of measurement is by an inflatable cuff wrapped around the upper arm. This cuff is called a sphygmomanometer. Like most physiological signals, blood pressure fluctuates continuously, but a measurement of 120/80 is considered normal for young adults. Large changes in blood pressure, usually an increase, accompany changes in emotional state [GRIN 78].

Related to blood pressure is blood volume. Blood vessels can constrict and dilate. Constriction is referred to vasoconstriction while vasodilation refers to the dilation of blood vessels. Vasodilation occurs when the activity of an organ increases, thus increasing its blood volume requirement. The vessels dilate allowing more blood to that organ. Along with the increase of blood volume to an active organ, a similar decrease occurs in inactive organs by vasoconstriction of the inactive organ vessels [GROS 67]. Vasoconstriction and vasodilation of blood

vessels in the periphery of the body is controlled by the SNS and not the PNS; therefore, blood volume is a good index into SNS changes that occur due to changing emotional states [GRIN 78]. This redistribution of blood can sometimes be easily seen when a person blushes from embarrassment or grows pale due to fear.

Blood volume measurement is most easily accomplished using a photoelectric plethysmograph as depicted in figure 6. It works on the principle that light is absorbed by tissue in proportion to the amount of blood in the tissue [GRIN 78]. A beam of light is directed into the skin and the resulting reflection is recorded by the photocell. The amount of light reflected from the skin is used as the index of blood volume.

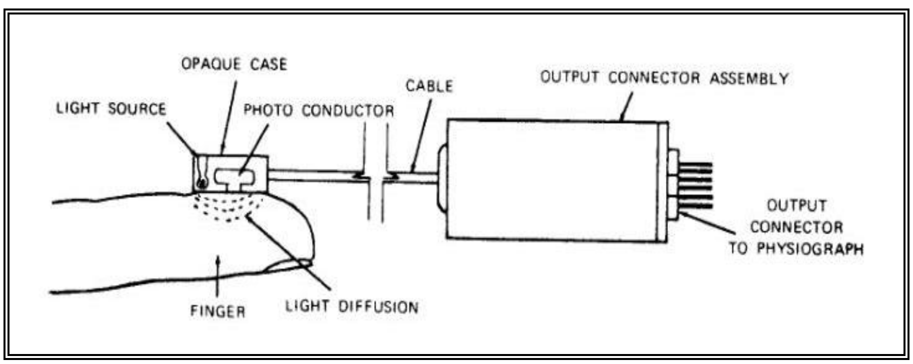

Figure 6. Photoelectric Plethysmograph (From: [GRIN 78]).

The fourth primary response to be discussed is electrodermal response (EDR). This response has become one of the most frequently measured signals in the field of psychophysiology [BOUC 92]. The more common all encompassing term is electrodermal activity (EDA). The basis of EDA is the electrical properties of the skin. These electrical properties are closely associated with

psychological processes such as attention and emotion [GRIN 78]. The skin's resistance, the most commonly measured response, is usually expressed as its reciprocal, skin conductance. Skin conductance is measured by applying a very small voltage across two electrodes placed on the skin, usually the palm or fingers [GRIN 78]. The activity of the sweat glands is directly responsible for changes in skin conductance. During emotional states, the skin becomes a better conductor of electricity. Skin conductance response may indicate the amount of affective arousal elicited by a situation or stimulus [BACK 00]. However, electrodermal activity can be influenced by both internal and external factors that may cause variation in the measured response. Studies show that EDA is affected by and dependent on ambient temperature [BOUC 92]. This dependency requires room temperature to be held as close to constant as possible and recorded along with other experimental data.

Internal influences of EDA are demographic in nature. Differences in age groups have been shown to exist but only between the third and fourth decades of life [BOUC 92]. As a body ages, the skin undergoes changes which commonly brings a decrease in EDA. A difference between genders has also been shown. Female participants tend to show a higher tonic EDA, while men show more activity under conditions of stimulation. This can be attributed to women having more sweat glands but men showing a greater gland flow [BOUC 92]. Ethnic differences also appear in EDA. This can be a result of the decreasing number of active sweat glands with increasing darkness of skin. All of these possible

differences need to be taken into account when measuring EDA.

All observable outward behavior is a result of muscular activity, which is measured as muscular potential, the fifth primary bodily response. Muscles are arranged in pairs of antagonists, flexors, and extensors [GROS 67]. Muscles are at the lowest level of tension when in a relaxed state (i.e. sleep) and increase as the body prepares for action. This tension is a frequent correlate of emotion [GRIN 78]. Measurement of muscular potential can be generally accomplished two ways, internally or externally. Internally requires the insertion of a needle into the muscle to record the electrical signal of the muscle and is commonly called an electromyogram (EMG). Externally does not require the piercing of the skin. Instead, electrodes are placed on the surface of the skin over the muscle of interest. This method is usually called either a surface EMG or muscle action potential (MAP). Unlike the other responses discussed so far, muscle fibers are innervated by the CNS and not the ANS [GRIN 78].

The last of the primary bodily responses to be discussed is the electroencephalogram (EEG) and related measures. The EEG measures electrical potentials continuously emitted by the brain. Electrodes placed on the scalp accomplish measurement of the EEG. The EEG is made up of many frequencies. Some of these frequencies show up more often than others. These frequencies are labeled delta waves (less than 4Hz), theta waves (4-7Hz), alpha waves (8-13Hz), and beta waves (greater than 13Hz). Alpha waves are the most common in the normal awake adult

and are associated with relaxation. Beta waves, the next most common, are associated with excited states. Theta waves are not normal for adults but are the most common in children. Delta waves are only common in certain stages of sleep [GRIN 78]. Since the EEG is a measure of brain activity, it reflects the activity of the CNS and not the ANS. A summary of the six primary responses is shown in table 6.

Table 6. Summary of Six Major Responses (From: [GRIN 78]).

Response System	**Primary Organ**	**Unit of Measurement**	**SNS Effect**	**PNS Effect**	**Recording Technique**
Heart rate (HR)	Heart	Beats per minute (BPM)	Increase	Decrease	Electrodes (placed on both sides of the heart)
Blood pressure (SBP, DBP, PP)	Heart and blood vessels	Millimeters of mercury pressure (mm Hg)	Increase	Decrease	Sphygmomanometer (with pressure cuff wrapped around the upper arm)
Peripheral blood volume (BV, PV)	Blood vessels	Relative change in millimeters (mm)	Decrease[a]	None	Photoelectric plethysmography
Electrodermal skin conductance (SCL, SCR)	Sweat glands	Micromhos	Increase	None	Electrical voltage (applied across electrodes on the skin)
Muscle potential (EMG, MAP)	Skeletal muscles	Microvolts or millivolts	None	None	Electrodes (placed on the skin above the muscle)
Electroencephalogram (EEG, CER, CNV)	Brain	Microvolts	None	None	Electrodes (placed on the scalp)

[a]This table lists only SNS and PNS effects; it is important to remember that determination from parts of the CNS are also important.

There are five other bodily responses that are related to emotions but are measured less frequently. These are

respiration, temperature, salivation, pupil size and gastric motility.

Respiration refers to breathing measures. The most common measures are respiration rate (breaths per minute), respiration period (time between breaths), and respiration volume (amount of air inhaled/exhaled). Respiration is controlled by both the CNS and ANS [GRIN 78].

Temperature is the measurement of the body's heat and is of two types, general or local. General temperature is a measurement of the body's overall thermal output and is obtained with either an oral or rectal thermometer. Local temperature is determined by attaching a thermistor or thermocouples to a particular body part, usually the hands or fingers. It is mostly determined by the amount of blood in that part of the body and is, therefore, controlled indirectly by the SNS.

Salivation refers to the amount of and composition of secretions. Salivary glands are activated/deactivated by the PNS and SNS. Output is activated by the PNS and deactivated by the SNS [GRIN 78].

Pupil size, another infrequent measurement, can range from 1.5mm to more than 9mm. The PNS controls constriction while the SNS controls dilation. The last bodily response to be discussed is gastric motility. This is usually measured by swallowing a monitoring device. The device can be either a magnet or a transmitter. The stomach and intestines are controlled by both the PNS and SNS [GRIN 78].

b. Physiological Patterns of Emotion

William James' theory of emotion theorized that a body's physiological responses could be used to recognize emotion. Critics of this argue that only certain aspects of emotion can be determined from physiology, but researchers have identified physiological signals that differentiate emotional states [HEAL 00].

There are two basic patterns used in emotional classification: arousal-valence and name classification. The arousal-valence classification is illustrated in figure 7.

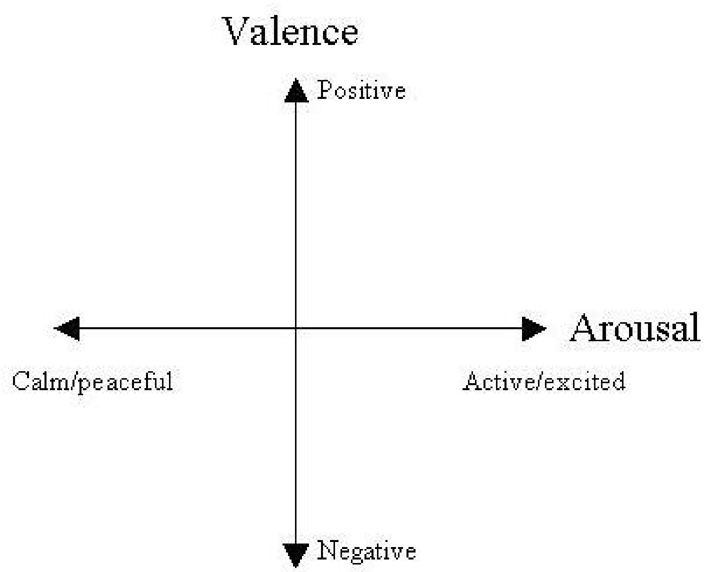

Figure 7. Depiction of the Arousal-Valence Space.

The arousal axis is characterized by a continuous response from calm and peaceful to active and excited. The valence axis ranges from negative to positive [VYZA 98]. The two dimensions of arousal and valence account for most of the variance in the measurement of emotions [DETE 98].

Name classification is somewhat more complex. Like most other situations where the true definition of a

concept is nebulous, emotion theorists have proposed sets of basic emotions as illustrated in table 7. As the table shows, one theorist's idea of the basic emotions is not necessarily another's. However, the table also shows that some emotions are members of more than one set [ORTO 88]. A difficulty of using name classification is the lack of clarity between the emotion categories. There is no way to determine the similarity or difference of emotions. This problem also makes it difficult to differentiate between examples of the same emotion [HEAL 00].

Table 7. Summary of Emotion Sets Proposed by different Theorists (From: [ORTO 88]).

Theorist	Emotion Set
James	Rage, fear, grief, love
Ekman	Anger, fear, sadness, enjoyment, disgust, (surprise)
Clynes	Anger, hate, grief, joy, love, romantic love, reverence, no emotion
Panskepp	Rage, fear, panic, expectancy
Plutchik	Anger, fear, anticipation, sadness, joy, acceptance, disgust, surprise
Izard	Anger, fear, distress, joy, surprise, interest, disgust, contempt, guilt, shame
Frijda	Anger, fear, distress, joy, surprise, aversion, contempt, pride, shame, desire

The role of physiology in assessing emotion has been highly debated. Much research has been done in trying to find physiological correlates which can be used to detect emotional state. While there is not a direct link between specific physiological response and emotional state, there may be a link between groups of physiological responses and emotional states. Cacioppo and Tassinary proposed a new model that uses mathematical combinations of features to

better distinguish emotional states [CACI 90]. They theorize that if features are combined, emotional states may be more distinguishable. Figure 8 depicts a theoretical mapping. It can be seen from figure 8 that the emotional states may be hard to distinguish if the physiological signals are considered separately. However, if the physiological signals are combined in different profiles, the emotional states may have a one to one mapping with physiological profiles.

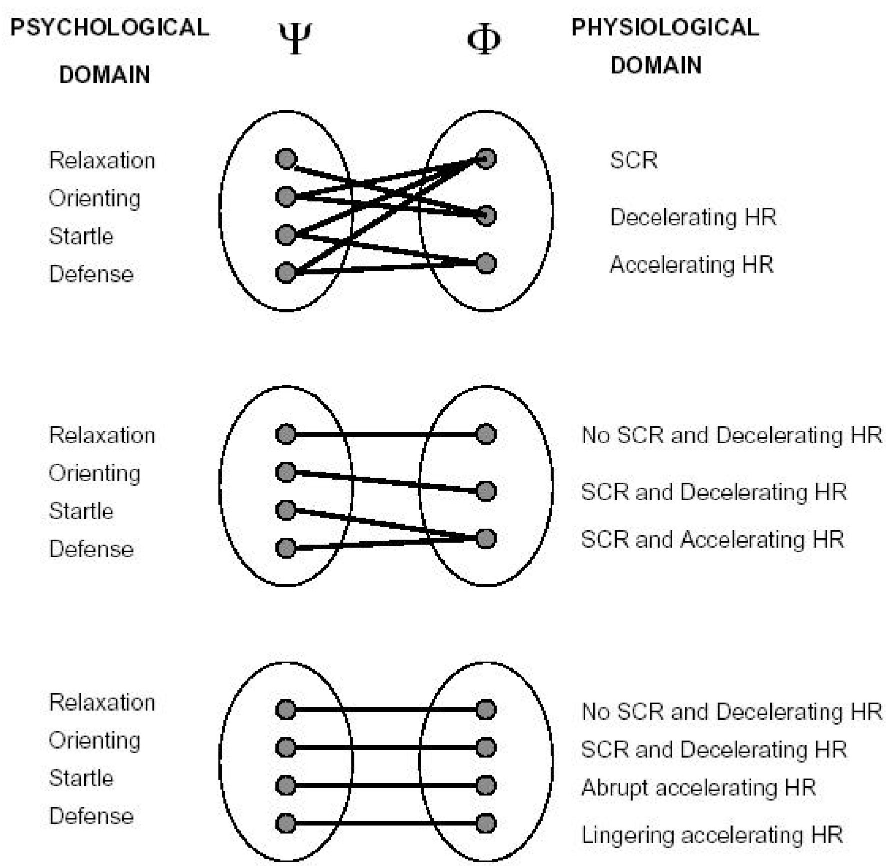

Figure 8. Combining Physiological Signals to Distinguish Emotional State (From: [CACI 90]).

c. Previous Research in the Physiological Aspects of Emotions

In the world of psychophysiology, much research has gone into trying to determine a person’s emotional state by measuring his physiological responses. While a direct mapping between emotion and physiological response has not been found, specific relationships have been found between the two most commonly cited dimensions of emotion – arousal and valence [DETE 98]. For valence, heart rate and facial muscle activity have been found to be good indicators while the frequency and amplitude of skin conductance response is a good indicator of arousal [SIMO 99][AX 64].

More recently, research in the area of affective computing has taken on the task of using the body’s physiological responses to determine the emotional state of the user. Affective computing has been defined as “computing that relates to, arises from, or deliberately influences emotions” [FERN 97]. The primary motivation behind this line of research is to develop computer interfaces that can actually determine the user’s emotional state and respond accordingly.

Initial research into the area of affective computing revolved around recognition of emotional state. Two experiments conducted in emotion recognition centered on intentionally expressed emotions. The experiments recorded four physiological signals (electromyogram, skin conductivity, blood volume pulse, and respiration), which were later processed for emotion recognition. Both resulted in emotion recognition with greater than chance probabilities [HEAL 98][VYZA 98]. Particularly, anger was easily differentiated from peaceful emotions and high

arousal states were distinguishable from low arousal states [HEAL 98].

A similar study attempted to determine when a user was frustrated, particularly the frustration experienced by a computer user, using physiological signals. The physiological signals measured were GSR, BVP, and EMG. These three signals have been shown to covary with increased frustration and anxiety [RISE 98]. Blood Volume Pulse has been identified as a measure of anxiety in response to a threat [SMIT 84]. Physiological signals, as measured, were able to differentiate between frustration states and non-frustration states using Hidden Markov Models [RISE 98].

Another more recent application of physiological monitoring is the SmartCar experiment by MIT. In this experiment, four physiological signals, EKG, EMG, respiration, and GSR, were used to detect driver stress in real life situations. The signals were chosen due to their recognition as useful indicators for assessing arousal and stress. Using combinations of features from multiple physiological signals improved the detection of stress over single features [HEAL 00].

4. Linking Objective and Subjective Measures of Presence

Presence is commonly defined as the subjective sense of “being there” in a mediated environment. Due to its subjective nature, the most common method of measuring presence is through post-test questionnaires. Measuring presence in this manner makes the measure dependent on

memory [DILL 00]. An aspect of presence that is usually disregarded in current definitions is the emotional aspect. Emotions are considered essential to how people experience the world around them [HUAN 99]. In fact, emotions are an every day part of life. How people experience a virtual world will also involve some aspect of their emotions.

The two most commonly cited dimensions of emotion are arousal and valence. As stated earlier, arousal is usually considered to range from excited and alert to calm and peaceful while valence is characterized as pleasant to unpleasant [DETE 98]. Arousal can be further conceived as a “drive state or a non-specific energizer of behavior” [DILL 00]. It is usually linked to the intensity of the experience and not the quality. Arousal is associated with physiological activity through the autonomic nervous system (ANS) [DILL 00][GRIN 78].

For this research, the measurements of electrodermal activity (EDA), heart rate (HR), and skin temperature will be recorded. Electrodermal activity has been shown to have a specific link to arousal and HR is linked to hedonic valence [DETE 98]. As the intensity of the stimulus increases, so does the body’s EDA. Electrodermal activity has also been shown to occur on the presentation of unexpected stimuli, which is commonly referred to as the orienting response. Meehan found that EDA has a high correlation with subjective presence ratings [MEEH 00]. Heart rate, on the other hand, is affected by the intensity of the emotional stimulus. Positive emotions involve greater heart activity than negative emotions [DILL 00]. Heart rate is also responsive to unexpected stimuli. Heart

rate decelerations are associated with the orienting response while accelerations are associated with defensive responses [GRAH 92]. Skin temperature is indicative of the amount of blood in the area. This is directly controlled by the vasoconstriction or vasodilation of the blood vessels, which is controlled indirectly by the sympathetic division of the autonomic nervous system (ANS) [GRIN 78]. Skin temperature has been shown to fall during emotional reactions [GROS 67] and is believed to be a valid measure for fear response [MEEH 00].

The subjective sensation of “being there” in a mediated environment is the basis for the definition of presence. But what does it mean to “be there”? Being physically present in an environment is not sufficient. How many times have you sat in a classroom but did not hear a word the instructor said? Or have you ever driven your car down a specific section of road that you are intimately familiar with only to realize once you reach your destination that you cannot remember how you got there? What is lacking is the psychological state of the participant. A person’s psychological state is partly made up of his emotional state and the perception of his body’s responses. Therefore, by measuring the body’s physiological responses when exposed to a virtual environment, the user’s emotional state is indirectly measured. This measurement of emotional state might yield a valid objective measure of presence.

III. METHOD

A. EXPERIMENT DESIGN

This thesis will assess the impact of sound delivery method on a user’s sense of presence. To do this, each participant will be placed in a VE and perform various tasks associated with the VE. Sound delivery will be the independent variable of this study. Physiological responses will be the primary dependent measures collected. These responses provide a good indication of the participant’s emotional state during exposure to stimuli (see ch. II, sec. 3). The next step is to make the logical link between emotional state and presence in a virtual environment (see ch. II, sec. 4). An additional effort will be made to investigate correlation between physiological responses and subjective questionnaire scores. This could establish a potential link between objective and subjective measures of presence. Figure 9 outlines this process.

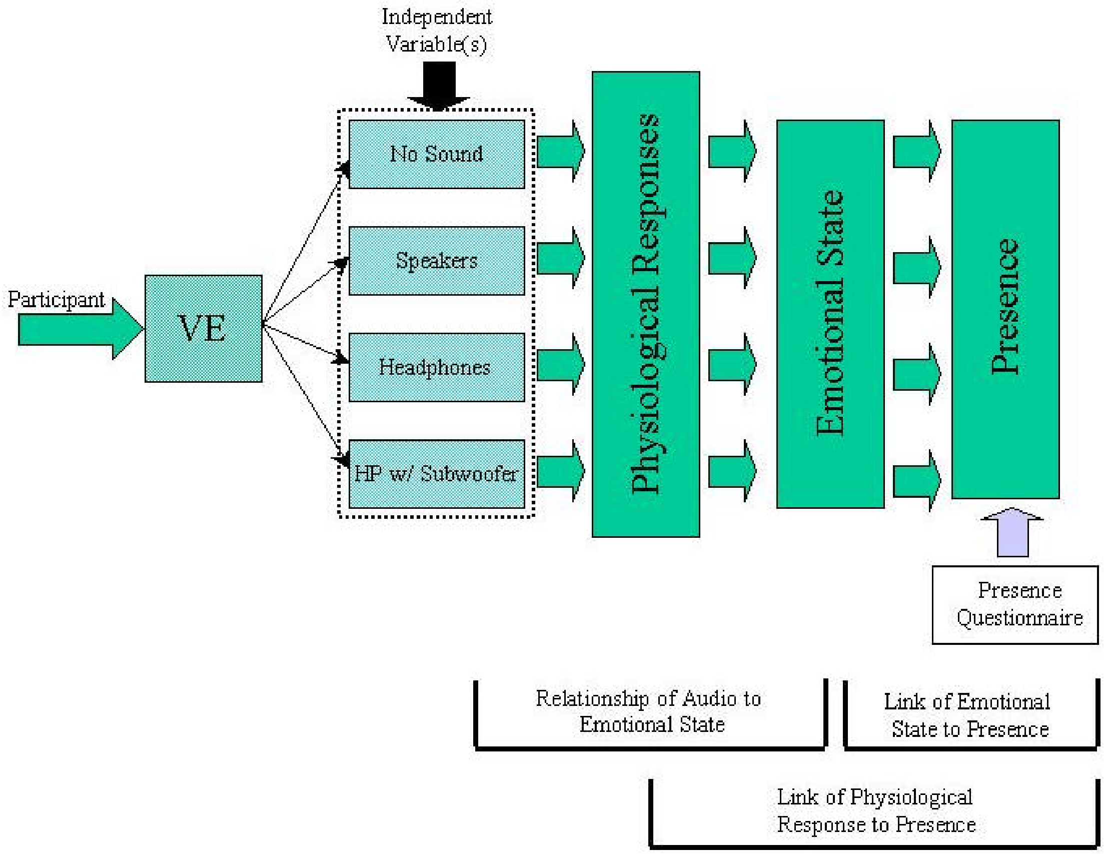

Figure 9. Experiment Design Logic.

B. VIRTUAL ENVIRONMENT SELECTION

The virtual environment required for this research had to meet two main criteria: excellent graphics and state of the art sound quality. Several first person shooter style games were evaluated but Medal of Honor: Allied Assault™ by EA Games™ (MOHAA) was the one selected. Medal of Honor: Allied Assault™ by EA Games™ was preferred primarily due to its superb graphics and impressive sound quality. The game is based on the European campaigns of World War II. While the scenarios have a historical perspective, it is much closer to reality than any of the other first person shooter games evaluated. Another selling point for this

game engine was its uniqueness. There was little concern about negative effects on presence due to previous exposure to the environment since MOHAA had recently been released (January 2002).

The MOHAA scenario chosen was the Omaha Beach Landing of the Normandy Invasion. This scenario provided a highly stimulating environment mentally, visually, and aurally. The participants started game play with full health at the shingle (see figures 10 and 11). The objective of the scenario was to clear out the bunkers defending the beach (see Appendix C). The reason for choosing the shingle starting point was the actual landing on the beach, although intense, appeared to be too difficult. The concern was that this difficulty would induce frustration in the novice player, thereby introducing inadvertent changes in physiological responses. Frustration would have an impact on the user's physiological responses and could obscure the physiological changes due to presence.

Figure 10. Overview Map of Omaha Beach (From: MOHAA).

Figure 11. Players View of Starting Point (From: www.gamespot.com).

C. EXPERIMENTAL DESIGN

The experiment was a between participant design with the sound delivery method being the independent variable. There were four delivery methods: No sound, Speakers, Headphones, and Headphones with subwoofer. All sound treatments had to be delivered at the same intensity at the ear of the listener. In order to do this, appropriate sound settings by treatment had to be determined. This was accomplished using a CEL Instruments Digital Sound Survey Meter (see Appendix F for specifications). The intensity was set at approximately 90 dB for each treatment. The bass was also adjusted to ensure that both subwoofer treatments received the same intensity. To accomplish this, the bass volume was measured for the speaker treatment and then the appropriate bass level was matched for the headphones with subwoofer treatment. The intensity settings by treatment are located in Appendix B.

A between participant design was chosen to minimize the effect of repeated exposure to the environment. Meehan showed that repeated exposure to a virtual environment decreases the user’s sense of presence [MEEH 00].

The dependent measures in this experiment were the participant’s physiological responses and their responses to subjective questionnaires. Three questionnaires were used in the experiment, an immersive tendencies questionnaire and two presence questionnaires (see Appendix E).

Immersive Tendencies Questionnaire: The immersive tendencies questionnaire (ITQ) consists of eighteen questions designed to identify real-world behaviors and

tendencies that may predict an individual’s potential to experience presence. The questions are rated on a seven point Likert-scale ranging from one to seven. An individual’s ITQ score is the sum of these values [SING 96]. An individual with a higher ITQ score is expected to also score high on the presence questionnaires. The ITQ has been used by other researchers in the study of presence [DARK 99][LAWS 98].

Presence Questionnaires: After exposure to the environment, the participants answered a combination of two questionnaires dealing with their sense of presence within the environment. The questions on the post questionnaire came from Witmer and Singer’s Presence Questionnaire (PQ)[SING 96] and Slater’s six questions on presence [SLAT 95]. Both of these questionnaires were rated on a seven-point Likert-scale similar to the ITQ. Witmer and Singer’s questionnaire consisted of twenty-four questions with presence scores being determined by summing up the ratings of these twenty-four questions. Slater’s questionnaire consisted of six questions with the presence score resulting from summing up the number of high answers (6’s or 7’s). These two questionnaires were used in an effort to investigate the correlation between the questionnaires since the authors have a difference of opinion on the definition of presence.

The physiological responses measured were heart rate, electrodermal activity (EDA) and temperature. These were chosen as outlined in the background section. EDA is an indicator of arousal, heart rate follows hedonic valence,

and temperature has been shown to be an indicator of fear response.

D. EQUIPMENT

Three computers were used in the experiment: two Dell™ Dimension 8100s and one Alienware™ computer (see Appendix F). One Dell contained the questionnaires while the other was used to record the participant's physiological responses. The environment was run on the Alienware™ computer using a Creative Labs Audigy Sound Card and presenting graphics on an NVIDIA Gefore3 graphics card.

The questionnaire computer made use of a program called MediaLab™ by Empirisoft™. MediaLab™ allows for easy generation and recording of questionnaire data. Once the participant answered the computer-based questionnaire, their answers were recorded and saved in a spreadsheet format for later analysis.

Physiological responses were monitored and recorded using Thought Technology's™ BioGraph™ 2.1 software and ProComp+™ distribution block (see Appendix F). ProComp+™ allows simultaneous recording of up to eight different physiological signals. BioGraph™ 2.1 also includes a simple statistical package that allows for easy calculation of the mean and variance for each recorded signal.

The headphone used was a Sennheiser™ model HD570 with an open design (see Appendix F). The same headphone was used for both the headphones and headphones with subwoofer treatments. The surround sound speaker configuration consisted of five Genelec™ 1031A active speakers with a single Genelec™ 1094A active 400 watt subwoofer system (see

Appendix F). The 1094A subwoofer was also used in conjunction with the headphones for the headphones with subwoofer treatment.

E. PARTICIPANTS

A total of eighty (80) participants were used in the study with a breakdown of seventy-six (76) males and four (4) females. The age breakdown of the participants is illustrated in figure 12. All participants were affiliated with the Naval Postgraduate School either as students, instructors, or employees. Prior experience with VEs varied among all subjects as well as first person shooter gaming experience. Gaming experience breakdown, as reported by the participant, is shown in figure 13. Participants were assigned to treatment groups at random.

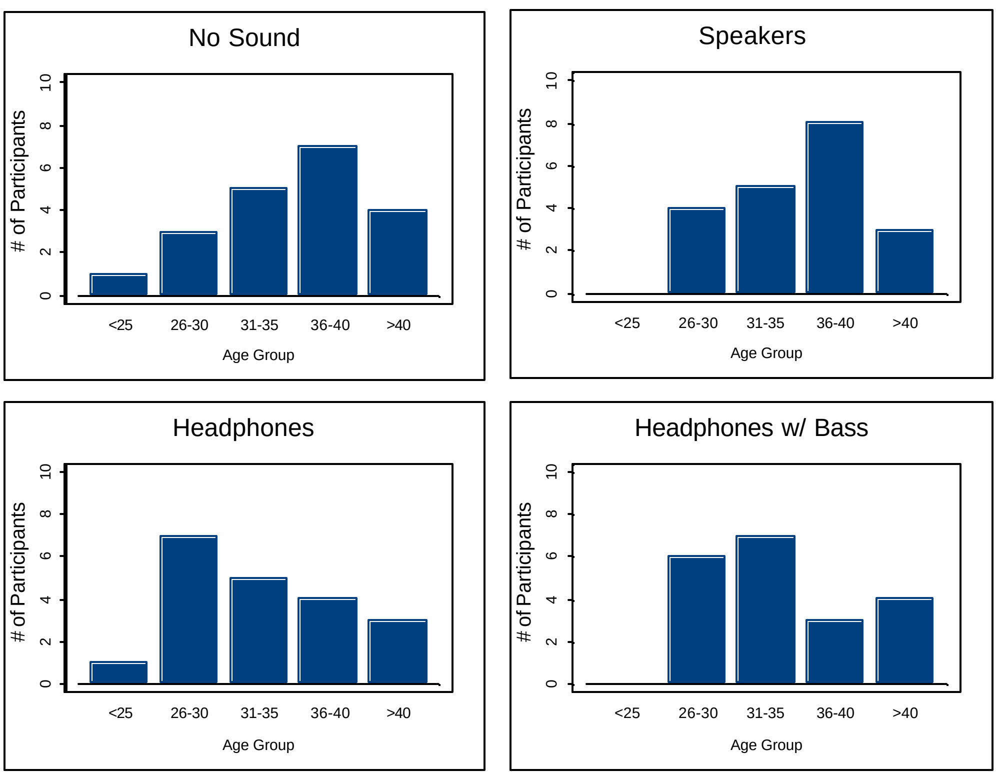

Figure 12. Age Breakdown by Condition.

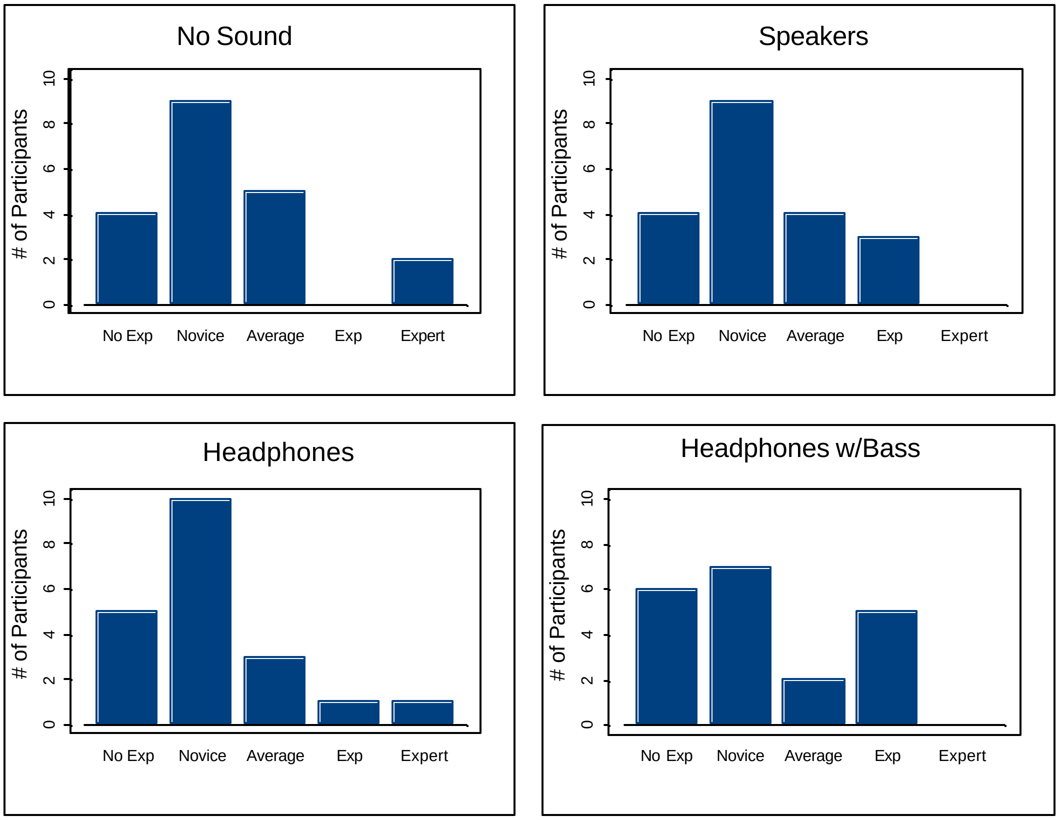

Figure 13. Gaming Experience by Condition.

F. PROCEDURES

Step One: Upon entering the lab, the participant was handed consent forms and asked to read and sign all three forms (Appendix D). The researchers then directed the participant into the Multimedia Lab and assigned the participant an identification number and treatment.

Step Two: Once seated in the Multimedia Lab, the participant was directed to follow the commands given by the "drill instructor" and complete the Basic Training scenario in Medal of Honor: Allied Assault™. This step allowed the participant to become familiar with the keys used to maneuver within the virtual environment.

Step Three: Upon completion of basic training, the participant was then directed to the questionnaire computer and asked to complete the pre-questionnaire (Immersive Tendencies Questionnaire).

Step Four: While the participant was answering the ITQ, the researchers set up the virtual environment in accordance with the participant’s assigned treatment (see step VII, Appendix B).

Step Five: After completing the ITQ, the participant was then directed back into the Multimedia Lab. Physiological sensors were attached to the participant in accordance with step VI of Appendix B. Once all sensors were attached, the participant was handed the Intel Brief (Appendix C) and asked to sit still and quiet while his two-minute baseline physiological responses were recorded. These recordings were saved under the filename of subxxbase, where xx is the participant’s ID number.

Step Six: When the participant indicated he was ready to continue, the video camera and physiological recording were started. The participant was then told to start the mission. After ten-minutes of physiological responses were recorded, the participant was told to stop. The physiological sensors were removed and the participant was directed back to the questionnaire computer to complete the post-test questionnaire.

IV. ANALYSIS AND DISCUSSION

A. INTRODUCTION

The analysis was done in two parts. First, the physiological responses were analyzed to determine the effect of sound delivery on the user's sense of presence. Next, the physiological responses were compared to the questionnaire data to investigate correlation.

For the following analyses, an α level of 0.10 was chosen. This less conservative level of significance was selected due to the variability in the individual differences of the participants, both in their physiological and subjective responses.

B. PRIMARY RESULTS

1. Primary Hypothesis

The method of sound delivery used in a virtual environment will have no significant effect on the user's sense of presence.

Baseline vs. Baseline: The first step in the analysis of the physiological responses was to determine if any physiological difference existed between the participants for each condition. Comparison of the baseline readings (heart rate, electrodermal activity, and temperature) by condition revealed no significant difference (see table 8). This was desired since any difference in baseline readings between conditions would obscure any further results.

Table 8. ANOVA of Baseline Physiological Response by Condition.

Physiological Response	***df***	**F-statistic**	**P**
Electrodermal Activity	(3, 76)	0.768	0.515
Heart rate	(3, 76)	1.662	0.182
Temperature	(3, 76)	0.989	0.403

Baseline vs. Condition: The next step was to compare the physiological responses by condition to their respective baseline readings. The results were mixed (see table 9).

EDA Results: Visual stimuli alone had no significant effect on EDA (no sound condition), but the addition of sound (speakers, headphones, and headphones with subwoofer) to the virtual environment created a significant change in EDA. Electrodermal activity is an indicator of arousal [DETE 98]. Thus, audio increases arousal and according to our operational definition of presence, leads to a change in a user's sense of presence.

Heart Rate Results: Heart rate was not significantly affected by any of the conditions.

Temperature Results: The only sound condition to show a significant effect on temperature was the speaker condition. Temperature has been shown to fall during emotional reactions [GROS 67] and is considered a valid measure of fear response [MEEH 00].

In summary, comparing the average baseline responses to the average responses during game play shows that sound affects the user's emotional state. Specifically, EDA is affected by the inclusion of sound to the environment

regardless of the delivery method. Temperature is significantly affected by the speaker condition only.

Table 9. Comparison of Baseline and Condition Physiological Responses.

Condition EDA vs Baseline EDA	***df***	**F-statistic**	**p**
No sound	(1, 38)	1.747	0.194
Speakers	(1, 38)	2.953	**0.094**
Headphones	(1, 38)	4.990	**0.031**
Headphones w/ subwoofer	(1, 38)	3.821	**0.058**
Condition Heart Rate vs Baseline Heart Rate	***df***	**F-statistic**	**p**
No sound	(1, 38)	0.729	0.398
Speakers	(1, 38)	1.770	0.191
Headphones	(1, 38)	0.865	0.358
Headphones w/ subwoofer	(1, 38)	1.601	0.214
Condition Temp. vs Baseline Temp.	***df***	**F-statistic**	**p**
No sound	(1, 38)	0.062	0.805
Speakers	(1, 38)	3.672	**0.063**
Headphones	(1, 38)	0.530	0.471
Headphones w/ subwoofer	(1, 38)	1.217	0.277

Condition vs. Condition: The next analysis compared the changes in the physiological responses between the different conditions.

EDA Results: No significant difference between conditions.

Heart Rate Results: No significant difference between conditions.

Temperature Results: Temperature was the only response to show a significant difference between conditions. This significance is shown between no sound

and any sound condition and between speakers and both headphone conditions. No significance was shown between headphones and headphones with subwoofer (see tables 10 and 11). A look at the average change in temperature by condition revealed speakers had the greatest effect on temperature with an average decline of 3.36 degrees Fahrenheit (see table 12). Again, temperature drops have been linked to changes in emotional state. This also coincides with the findings tabulated in table 9.

A similar analysis with the exclusion of suspected contaminators (pilot study participants, previous Medal of Honor players, and any identified outliers) also resulted in only a significant effect in temperature.

Table 10. Comparison of Change in Physiological Responses by Condition.

Change in Physiological Response by Condition	***df***	**F statistic**	**p**
Electrodermal Activity (EDA)	(3, 76)	0.755	0.523
Heart Rate (HR)	(3, 76)	0.306	0.821
Temperature	(3, 76)	7.756	**0.0001**

Table 11. Comparison of Change in Temperature.

Condition versus Condition	***df***	**t Critical (two-tailed)**	**p**
No sound vs Speakers	19	1.729	**0.00001**
No sound vs Headphones	19	1.729	**0.060**
No sound vs Headphones w/subwoofer	19	1.729	**0.014**
Speakers vs Headphones	19	1.729	**0.003**
Speakers vs Headphones w/subwoofer	19	1.729	**0.056**
Headphones vs Headphones w/subwoofer	19	1.729	0.221

Table 12. Average Change in Temperature by Condition.

No sound	Speakers	Headphones	Headphones w/ Subwoofer
-0.60	-3.36	-1.70	-2.35

2. Secondary Hypothesis

Physiological responses of heart rate, electrodermal activity, and temperature can be used as objective measures of presence.

Although the physiological results met our criteria for measuring presence using our operational definition of presence, we wanted to determine if these physiological measures correlated with questionnaires commonly used to measure presence. The analytical tool chosen for this procedure was the Spearman Rank Correlation due to its applicability for non-linear relationships [MEEH 00].

Questionnaire Analysis: The first step in the questionnaire analysis was to look at the relationship between the scores on the Immersive Tendencies Questionnaire (ITQ) and the Presence Questionnaire (PQ). The next step was to break apart the post questionnaire into the Witmer and Singer PQ and the Slater questions (SQ) and analyze this data to see if a correlation between questionnaires exists.

A Spearman rank correlation of the ITQ score and PQ score reveals $r_s = 0.46$, $\underline{p} = 0.0$. The results indicate a high overall correlation between the two questionnaires exists. This is not surprising since the purpose of the ITQ is to measure a person's tendency to become immersed. It follows that those who score high on the ITQ should correspondingly score high on the PQ (see figure 14). The

no sound condition was the only one in which some participants' PQ scores were lower than their ITQ scores. This result was expected since three of the PQ questions deal specifically with audio, where the no sound condition scores would obviously be lower.

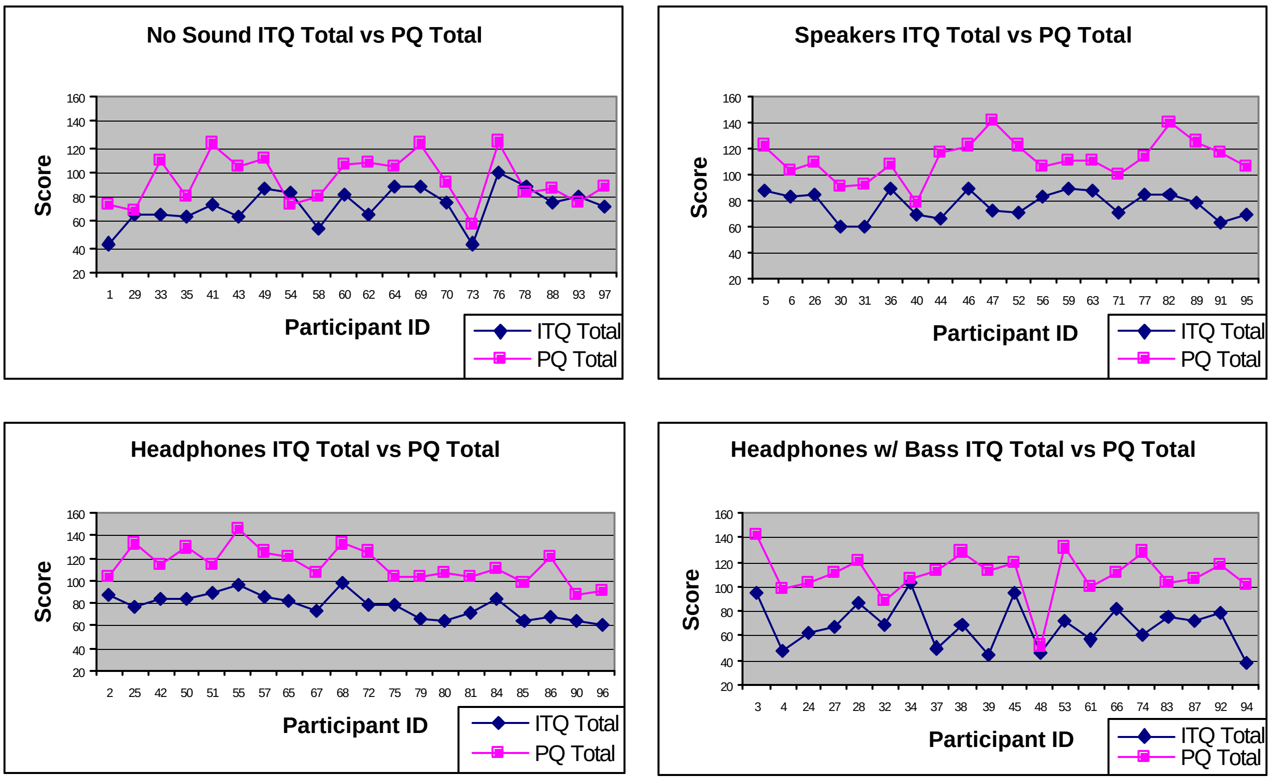

Figure 14. Plot of ITQ and PQ Scores by Condition.

Further analysis of the questionnaire data was used to determine what affect the sound delivery method had on a user's sense of presence while in the virtual environment. Figure 15 shows the average ITQ and PQ scores by sound delivery method. As can be seen from figure 15, a difference exists between the no sound condition and any of the sound conditions. Of interest here is the similarity of the speaker and headphone condition. This implies that

there is marginal difference, if any, between the 5.1 surround sound speakers and the headphones. Also of interest is the drop in the PQ average score for the headphones with subwoofer condition. This may be attributed to the lower ITQ average, which implies that the participants in the headphones with subwoofer condition were less likely to become immersed in the environment. Analysis of variance testing of the total PQ score against the type of sound delivery method resulted in $F(3,76) = 5.918$, $p = 0.001$. Therefore, sound plays an important role in aiding the user in developing a sense of presence in a virtual environment.

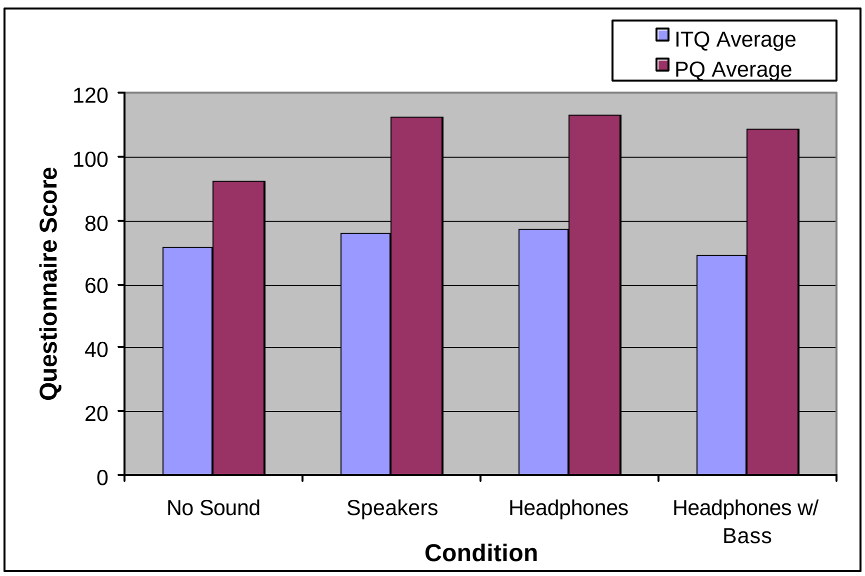

Figure 15. Average ITQ and PQ Scores by Condition.

Since a significant difference was identified between sound treatments, additional analysis was required to determine where that difference occurred. To identify the reason for the difference, paired-wise t-tests between treatments were utilized and results are shown in table 13. This shows that while sound makes a difference on a user’s

sense of presence, the method of delivery does not. Removing the sound questions results in only a significant difference in the no sound versus headphones comparison.

Table 13. Comparison of PQ Scores between Conditions.

Condition	**df**	**t Critical**	**p**	**p (w/o sound questions)**
No sound vs Speakers	19	1.729	**0.005**	0.170
No sound vs Headphones	19	1.729	**0.0006**	**0.072**
No sound vs Headphones w/subwoofer	19	1.729	**0.015**	0.323
Speakers vs Headphones	19	1.729	0.706	0.771
Speakers vs Headphones w/subwoofer	19	1.729	0.655	0.676
Headphones vs Headphones w/subwoofer	19	1.729	0.474	0.561

To further illustrate the effect of sound on presence according to the questionnaires, figure 16 shows the relationship of average ITQ and PQ scores to the score of the PQ without the sound related questions. Analysis of the PQ and PQ without sound questions scores results in no significant difference. One might ask why the no sound condition score dropped when the sound questions were removed from the total. As stated earlier, the questions are rated on a one to seven scale. This means that the lowest possible answer still contributes a value of one to the total score. Zeroing the scoring on the questionnaire only scales down the graphs, but the overall trends remain the same. Also, some of the participants in the no sound condition rated the audio questions higher than the lowest possible score. Initially, these answers were thought to be erroneous. Further investigation revealed that some of the no sound condition participants were unaware they had the no sound condition. This is just one example of the inherent problems with subjective questionnaires.

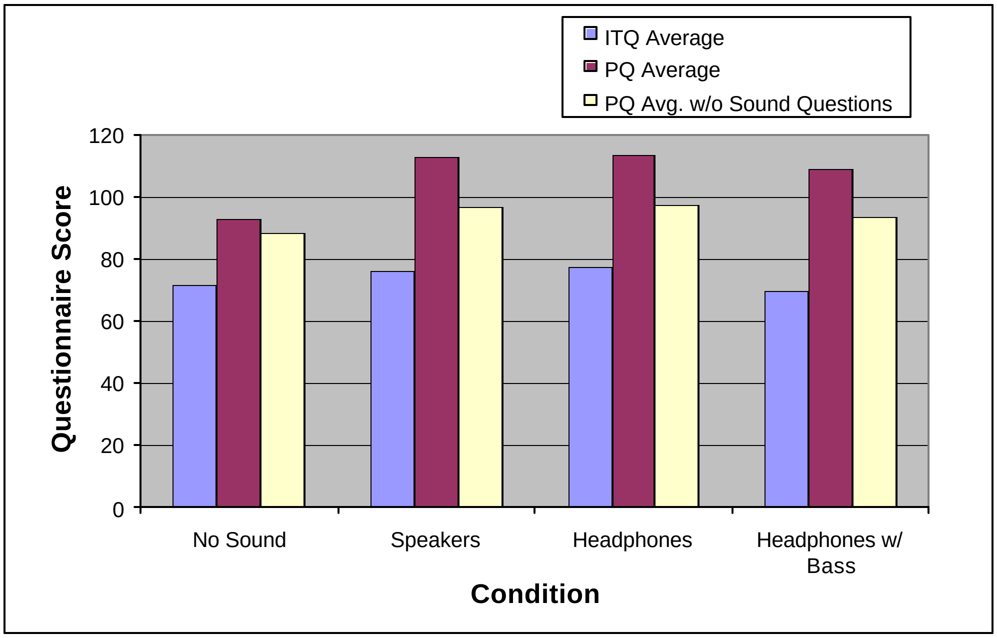

Figure 16. Average Scores of ITQ, PQ, and PQ w/o Sound Questions.

The next step in the questionnaire analysis was the comparison of the PQ scores to the Slater question scores. A visual examination of the graph of average answer values appears to show very little difference (see figure 17), but a statistical analysis shows a significant difference ($F(1,75) = 79.118$, $\underline{p} = 0.000$). In spite of this difference, the two questionnaires are highly correlated ($r_s = 0.680$, $\underline{p} = 0.000$). Further analysis shows no significance when comparing the Slater average answer value between conditions ($F(3,76)$, $\underline{p} = 0.151$).

This indicates that the PQ may have been the better subjective measure of presence for this particular environment. The PQ consisted of twenty-four questions ranging from the participant's sense of presence within the environment to immersive aspects of the environment (video quality, interface design issues, audio aspects, etc.).

Slater’s six questions deal entirely with the participant’s cognitive recollections of the virtual environment.

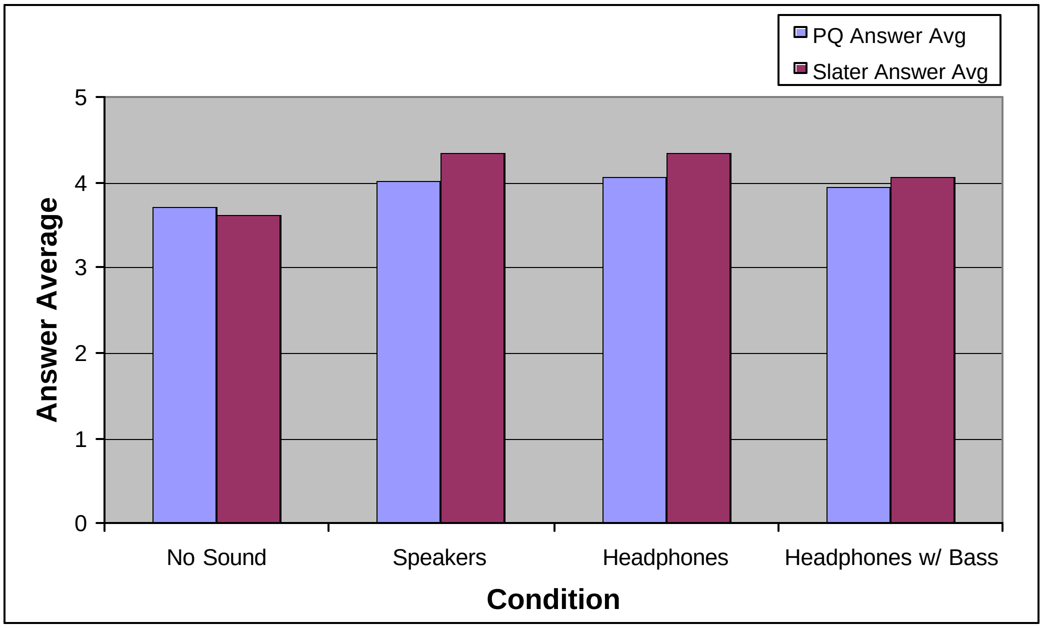

Figure 17. Average PQ and SQ Answer Values.

Comparing Physiological Responses to Questionnaires: The first step in this analysis consisted of performing ANOVAs to determine if any significant difference existed between the physiological responses and the PQ scores. The results of the comparison are shown in table 14. The results show a significant difference between the PQ score and changes in physiological responses in the conditions of no sound and headphones only, with or without outliers. Electrodermal activity (EDA) and heart rate (HR) were the only responses to show this effect.

Table 14. PQ Score vs Physiological Response by Condition

Condition Change in EDA	***df***	**F statistic**	**p**
No sound	(1, 16)	5.283	**0.035**
No sound w/o outlier(s)	(1, 15)	7.291	**0.016**
Speakers	(1, 16)	0.400	0.536
Headphones	(1, 16)	7.035	**0.017**
Headphones w/o outlier(s)	(1, 15)	0.499	0.491
Headphones w/ Subwoofer	(1, 16)	0.222	0.644
Condition Change in HR	***df***	**F statistic**	**p**
No sound	(1, 16)	0.598	0.451
No sound w/o outlier(s)	(1, 15)	9.259	**0.008**
Speakers	(1, 16)	1.965	0.180
Headphones	(1, 16)	4.019	**0.062**
Headphones w/o outlier(s)	(1, 15)	5.142	**0.039**
Headphones w/ Subwoofer	(1, 16)	0.299	0.592
Condition Change in TEMP	***df***	**F statistic**	**p**
No sound	(1, 16)	1.125	0.305
No sound w/o outlier(s)	(1, 15)	1.574	0.229
Speakers	(1, 16)	0.154	0.700
Headphones	(1, 16)	0.502	0.489
Headphones w/o outlier(s)	(1, 15)	0.223	0.642
Headphones w/ Subwoofer	(1, 16)	0.009	0.925

Additional tests were conducted to identify other factors correlated to the PQ scores. Factors evaluated were computer gaming experience, caffeine, age, gender, and sleep. Gaming and caffeine were the only two factors to show significant correlation ($r_s = 0.528$, $\underline{p} = 0.0$ and $r_s = 0.187$, $\underline{p} = 0.096$, respectively). Based on these results, a multi-comparison ANOVA comparing PQ scores with condition and all two and three-way interactions of changes in EDA, HR, and temperature, gaming, and caffeine was conducted. The results are shown in table 15 and figure 18. Again, it showed any sound condition had an effect on the participants' PQ score but delivery method showed no significance.

Table 15. Multi-comparison ANOVA Results.

Conditions	Estimate	Std. Error	Lower Bound	Upper Bound
No sound – Speakers	**-20.60**	**6.86**	**-36.6**	**-4.58**
No sound – Headphones	**-22.30**	**5.93**	**-36.2**	**-8.51**
No sound – Headphones w/ Subwoofer	**-28.90**	**6.11**	**-43.1**	**-14.60**
Speakers – Headphones	-1.75	6.82	-17.7	14.20
Speakers – Headphones w/ Subwoofer	-8.28	7.04	-24.7	8.15
Headphones – Headphones w/ Subwoofer	-6.52	6.31	-21.3	8.21

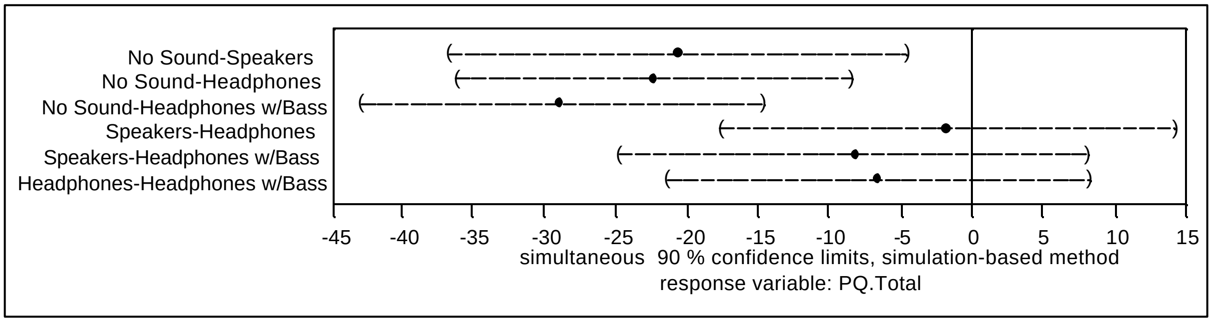

Figure 18. Graph of Multi-comparison ANOVA Results.

A similar analysis of the relationship between physiological responses and the Slater presence questions revealed no significant difference on any response or condition. Again, this could be attributable to the cognitive basis of the questions.

The last step in the analysis was to determine if any correlation existed between the measured physiological responses and the presence questionnaire scores. Again, the Spearman Rank Correlation was the analytical tool of choice. A correlation exists between EDA and PQ score (r_S = 0.349, $\underline{p}$ = 0.002) and HR and PQ score (r_S = 0.247, $\underline{p}$ = 0.028), but not temperature and PQ score. Similar correlation tests on physiological responses and the Slater

presence questions (SQ) score resulted in a correlation between EDA and SQ score ($r_s = 0.230$, $p = 0.041$). This again indicates that the PQ may have been the better subjective measure of presence for this particular environment.

C. SUMMARY

The analysis of the effect of sound delivery method indicates that sound had a significant effect on the user's sense of presence in this virtual environment. Visual stimuli alone had no significant effect on EDA (no sound condition), but the addition of sound (speakers, headphones, and headphones with subwoofer) in the virtual environment created a significant effect on this response. Electrodermal activity is an indication of arousal, which is considered a primary dimension of emotion [DETE 98]. The speaker delivery method was shown to have a significant effect on temperature. Temperature has been shown to fall during emotional reactions [GROS 67] and is considered a valid measure of fear response [MEEH 00].

The use of physiological responses as an objective measure of presence appears to be feasible. While temperature was the only response to be affected by the sound delivery method, electrodermal activity and heart rate indicate a significant correlation to the subjective PQ scores. Electrodermal activity was the only physiological response to correlate with the Slater questions score.

Presence questionnaire results show a significant difference between no sound and any sound condition. This

indicates that headphones elicit an equivalent subjective level of presence as the high-end surround sound speakers. The addition of a subwoofer to the headphones had no significant effect.

Although both the Witmer and Singer Presence Questionnaire and Slater’s six presence questions have been used as subjective means for gauging a user’s sense of presence, these two questionnaires do not measure the same aspects of presence. The PQ encompasses more attributes of the virtual environment, including sound (the independent variable of this experiment), while Slater’s questions concentrate primarily on the cognitive aspects of the environment. Due to these facts, the PQ is a more appropriate subjective measure for this virtual environment.

V. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The purpose of this study was two-fold. First, the effect of sound delivery method on a user's sense of presence in a virtual environment was determined based on the participants' physiological responses. Second, the physiological responses were compared to presence questionnaire scores to determine if a correlation exists.

The analysis of the effect of sound delivery method indicates that sound had a significant effect on the user's sense of presence in this virtual environment. Visual stimuli alone had no significant effect on EDA (no sound condition), but the addition of sound (speakers, headphones, and headphones with subwoofer) in the virtual environment created a significant effect on this response. Electrodermal activity, especially the frequency and amplitude, is a known indication of arousal [SIMO 99][AX 64]. Arousal is considered to be one of the two most commonly cited dimensions of emotion [DETE 98]. Thus, the addition of sound to a virtual environment affects the level of presence by inducing arousal in the user.

Temperature was shown to decrease in the speaker condition more than in either of the headphone conditions. Temperature has been shown to fall during emotional reactions [GROS 67]. It is also considered a valid measure of fear response [MEEH 00]. Headphones with subwoofer, although not reaching significance, had the second largest drop in temperature. This is a potential indication that the subwoofer played a part in eliciting fear in the user.

This occurs as the body withdraws blood from the extremities and sends more to the vital organs as needed for “fight or flight”. The advantage the surround sound speakers had over any headphone condition was spatialization. This added ability to localize sound may have induced a more pronounced fear response.

The physiological responses of electrodermal activity EDA and HR showed significant correlation to the presence questionnaire scores, but temperature did not. This follows the results found in a previous study by Meehan [MEEH 00]. The use of the physiological responses of EDA and HR as an objective measure of presence appears valid. However, the questionnaires used do not explicitly measure any kind of emotional response. Witmer and Singer’s Presence Questionnaire, although they consider immersion a psychological state that is a prerequisite for presence [WITM 98], measures how involving the VE was or how natural the interaction was but not how it made the user feel emotionally. Slater’s questions, on the other hand, only deal with the cognitive aspects of the environment such as how the user remembered the experience. In order to concretely link physiological responses to presence, a questionnaire that asks how the environment made the user “feel” (i.e. afraid, excited, anxious, etc.) may be required.

The results of the subjective questionnaires indicate that sound plays an important part in eliciting presence in the user. However, the method of delivery of the sound has no significant effect. These findings indicate that the use of headphones have the same effect on presence as a 5.1

surround sound speaker system. The use of headphones in a virtual environment decreases the system cost and required area for setting up the environment, two extremely important considerations for the military.

However, subjective questionnaires have inherent problems. In this study, some of the no sound condition participants rated the sound related questions above the minimum values. Upon detection of the higher values, investigation revealed that some of the no sound participants did not realize they had no sound during game play. Such obviously erroneous readings can skew the data. Fortunately in this study, removing these participants' results from the database did not dramatically change the findings.

The results of this study demonstrated the inherent problems with questionnaires. Automatic reactions such as physiological responses bypass these problems and provide a more reliable measure of presence. Due to these facts, it is our conclusion that physiological responses are a more effective measure of presence. The lack of complete correlation of physiological responses to subjective questionnaires only indicated that the questionnaires did not contain the appropriate questions to fully measure the sense of presence.

B. RECOMMENDATIONS

The scenario selected in Medal of Honor: Allied Assault™ was not conducive to localizing sound. It contained many explosions that surrounded the player. Therefore, the necessity to localize sounds was not a

requirement for this particular game scenario. A more fitting scenario to determine the differences between headphones and surround sound speakers would be one that required the user to determine the direction of sound(s) in order to successfully complete the mission.

The baseline physiological readings were taken upon arrival in the lab after the participant completed the training scenario and the pre-questionnaire. This may have not allowed enough time for the participant’s signals to return to a rest state after walking to the lab (some had to walk further than others). A fifteen-minute rest time before taking baseline readings (after completing both the training scenario and pre-questionnaire) might have lead to more accurate representations of baseline readings. Also, the participants read the Intelligence Brief while their baseline readings were being recorded. A better way may have been to “isolate” them while taking baseline readings. Having the participant sit in a relatively dark and silent room may have been more appropriate.

During game play, most of the participants would ask the observer questions about the scenario. This inevitably detracted from their sense of presence in the environment. Notifying the participants that no questions would be answered after game play commenced would have minimized this possible distraction.

The experiment conducted was a between-subjects design in order to minimize any adverse effect due to previous exposure to the environment. One of the deciding factors in using Medal of Honor: Allied Assault™ as the environment was its uniqueness. Having recently been released, the

threat of previous exposure was expected to be minimal. However, there were four participants who had played the game before the experiment. Removing their data from the analysis resulted in no significant change in the outcomes. This indicates that previous exposure, although shown to have an effect on presence in previous research [MEEH 00], had minimal effect in this experiment. A within-subjects design may result in more pronounced effects due to less variability caused by individual differences.

All participants were subjected to surround sound speaker sound while conducting the training scenario, although at a much lower level than game play. While this was probably not a problem for those that received a sound condition, the no sound participants may have been inadvertently biased due to a preconceived expectation of sound. This bias may have influenced their responses on the subjective questionnaires. Having all participants complete the training scenario with only verbal cues from the experimenters may have been a better method, thereby eliminating any unwanted influence.

C. FUTURE WORK

Although this experiment shows that the physiological responses of EDA and HR correlate with an individual’s subjective sense of presence while in a virtual environment, further work is required to corroborate these findings. Some future work that may be done to corroborate this data follows.

One of the drawbacks of using human participants is the variability between individuals. In order to minimize

this variability, large sample sizes are needed. Rerunning the experiment, adding the data to the current data, and then performing analysis on the whole data set may provide stronger evidence either for or against physiological responses being used as objective measures of presence.

Although the scenario chosen for this experiment provided captivating sound, it did not provide many localizable sounds. The majority of the sound came from artillery explosions occurring all around the player. Selecting a scenario that provides sounds that are more localizable may show a significant difference between sound delivery methods. The use of a scenario with localizable sounds would also permit the use of head related transfer functions (HRTF). The experiment could incorporate HRTFs to also determine the affect of sound delivery methods on the user’s sense of presence.

Another objective method of presence measurement is postural response. Video of the participants during game play was taken but not analyzed due to time constraints. Analysis of the video could be done to compare postural responses to both physiological responses and presence questionnaire totals. Effort would be required to develop a metric for determining significant movement since head tracking was not employed. Further experimentation using a method of tracking postural responses could also be used to corroborate these findings.

This experiment concentrated on the effect of sound delivery method on the user’s sense of presence. The questionnaires used concentrated primarily on other than the sound aspects of the environment. Only three of the

twenty-four questions dealt directly with sound. Altering the immersive qualities of the environment by other than sound (i.e. HMD, big screen TV, CAVE, etc.) could greatly affect the individual's sense of presence and their physiological responses. Although this will not aid in determining which sound delivery method has the greatest effect on presence, it may aid in determining the correlation between physiological responses and an individual's sense of presence.

Due to the subjective nature of presence, questionnaires are the primary means of measurement. The questionnaires used in this experiment are only two of the handful currently available. Running the experiment with a different presence questionnaire may further validate the use of physiological responses as an objective measure of presence. A comparison of the different questionnaires may also contribute to this body of work. Furthermore, since physiological responses are correlates of emotion, a questionnaire asking emotion related questions might be more appropriate to determine the link between physiological responses and presence. Development of such a questionnaire would most assuredly be helpful in this endeavor.

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LIST OF REFERENCES

[ANDR 80] Andreassi, J.L., *Psychophysiology*, Oxford, 1980.

[AX 64] Ax, A.F., *Goals and methods of psychophysiology, Psychophysiology*, 1(1), pp. 8-25, The Williams & Wilkins Co, 1964.

[BACK 00] Backs, R.W., & Boucsein, W., (Eds.), *Engineering Psychophysiology*, Lawrence Erlbaum Associates, 2000.

[BLAC 70] Black, P., (Ed.), *Physiological Correlates of Emotion, Academic* Press, 1970.

[BOUC 92] Boucsein, W., *Electrodermal Activity,* Plenum Press, 1992.

[DARK 99] Darken, R.P., Bernatovich, D., Lawson, J., & Peterson, B., "Quantitative measures of presence in virtual environments: The role of attention and spatial comprehension," *Cyberpsychology and Behavior*, 2(4), pp. 337-347, 1999.

[DARW 72] Darwin, C., *The expression of the emotions in man and animals,* D. Appleton, 1872.

[DETE 98] Detenber, B.H., Simons, R.F., and Bennett, G.G., Jr., "Roll 'em: The effects of picture motion on emotional responses," *Journal of Broadcasting and Electronic Media,* 42, pp. 113-127, 1998.

[DILL 00] Dillon C., Keogh E., Freemen J., and Davidoff J., "Aroused and Immersed: The Psychophysiology of Presence", [http://homepages.gold.ac.uk/immediate/Conferences/Presence2000/P2000-dillon.html]. 2000.

[DINH 98] Dinh, H.Q, Walker, N., Song, C., Kobayashi, A., and Hodges, L.F., "Evaluating the importance of multi-sensory input on memory and the sense of presence in virtual environments," IEEE Proceedings of Virtual Reality 99, 1998.

[DURL 95] Durlach, N.I., Mavor, A.S. & Committee on Virtual Reality and Development, *Virtual Reality: Scientific and Technological Challenges,* National Academy Press, 1995.

[FERN 97] M.I.T. Media Laboratory Technical Report 446, Stochastic *modeling of physiological signals with hidden Markov models: A step toward frustration detection in human-computer interfaces*, by R. Fernandez, 1997.

[FREE 99] Freeman J., Avons S.E., Pearson D.E., and Ijsselsteijn W.A., "Effects of Sensory Information and Prior Experience on Direct Subjective Ratings of Presence," *Presence*, v.8(1), February 1999.

[GRAH 92] Graham, F.K., "Attention: The heartbeat, the blink and the brain," in Campbell, B.A. and others (eds.), *Attention and Information Processing in Infants and Adults: Perspectives from Human and Animal Research,* Lawrence Erlbaum Associates, 1992.

[GRIN 78] Grings, W.W, & Dawson, M.E., *Emotions and Bodily Responses: A Psychophysiological Approach,* Academic Press, 1978.

[GROS 67] Grossman, S.P., *A Textbook of Physiological Psychology,* John Wiley & Sons, Inc, 1967.

[HEAL 98] M.I.T. Media Laboratory Perceptual Computing Section Technical Report 473, *Digital processing of affective signals*, by J. Healey and R. Picard, 1998.

[HEAL 00] Healy, J.A., *Wearable and Automotive Systems for Affect Recognition from Physiology,* Ph.D. Dissertation, Massachusetts Institute of Technology, Cambridge, Massachusetts, May 2000.

[HEAL 00a] M.I.T. Media Laboratory Perceptual Computing Section Technical Report No. 525, *SmartCar:* Detecting Driver Stress, by Healey J. and Picard R., 2000

[HEET 92] Heeter, C., "Being there: The subjective experience of presence*," Presence: Teleoperators and Virtual Environments*, 1(2), pp. 262-271, 1992.

[HEIL 92] Heilig, M.L., "El Cine del Futuro: The Cinema of the Future", Presence, 1(3), pp. 279-292.

[HOHM 66] Hohmann, G.W. "Some effects of spinal cord lesions on experienced emotional feelings," *Psychophysiology*, 3, pp. 143-156, 1966.

[HOLM 00] Holman, T. *Surround Sound Up and Running.* Focal Press, 2000.

[HUAN 99] Huang M.P. and Alessi N.E., "Presence as an Emotional Experience," in Westwood, J.D. and others (eds.), *Medicine meets virtual reality: the convergence of physical and information technologies options for a new era in health care,* IOS Press, 1999.

[IJSS 00] Ijsslesteijn, W.A., de Ridder, H., Freeman, J., & Avons, S.E. "Presence: Concept, determinants and measurement," from the Proceedings of the SPIE, Human Vision and Electronic Imaging V, San Jose, California, January 2000.

[IJSS 00a] Ijsslesteijn, W.A., de Ridder, H., Freeman, J., Avons, S.E., & Pearson, D. “Towards an objective corroborative measure of presence: Postural responses to moving video,” paper presented at the 3rd International Workshop on Presence, Delft, Netherlands, March 2000.

[JAME 90] James, W., *The Principles of Psychology.* Holt, 1890.

[KALA 00] Kalawsky R.S., “The Validity of Presence as a Reliable Human Performance Metric in Immersive Environments,” paper presented at the 3rd International Workshop on Presence, Delft, Netherlands, 27-28 March 2000.

[LAWS 98] Lawson, J.P., “Level of Presence or engagement in one experience as a function of disengagement from a concurrent experience,” Master’s Thesis, Naval Postgraduate School, Monterey, California, September 1998.

[LAMP 94] Lampton, D.R., Knerr, B.W, & Goldberg, S.L., “The Virtual Environment Performance Assessment Battery (VEPAB),” *Presence: Teleoperators and Virtual Environments*, 3(2), pp. 145-157, 1994.

[LESS 00] Lessiter J., Keogh E., Freemen J., & Davidoff J., “Development of a New Cross-Media Presence Questionnaire: The ITC-Sense of Presence Inventory,” paper presented at the 3rd International Workshop on Presence, Delft, Netherlands, 27-28 March 2000.

[LESS 01] Lessiter J., Freemen J., & Davidoff J., “Really Hear? The Effects of Audio Quality on Presence,” paper presented at the 4th International Workshop on Presence, Philadelphia, Pennsylvania, 21-23 May 2001.

[LOMB 97] Lombard, M. & Ditton, T., "At the heart of it all: The concept of presence," *The Journal of Computer-Mediated Communication (on-line),* 3(2), [http://www.ascusc.org/jcmc/vol3/issue2/lombard]. 1997.

[MEEH 00] Meeban M., "An Objective Surrogate for Presence: Physiological Response," paper presented at the 3rd International Workshop on Presence, Delft, Netherlands, 27-28 March 2000.

[ORTO 88] Ortony, G.C, and Collins, A., *The cognitive Structure of Emotions,* Cambridge University Press, 1988.

[RISE 98] Riseberg, J., Klein, J., Fernandez, R., Picard, R.W., "Frustrating the user on purpose: Using biosignals in a pilot study to detect the user's emotional state", paper presented at the Proceedings of American Computing Machines, Computer Human Interaction 98, 2, pp. 227-228, 1998.

[SHER 92] Sheridan, T.B., "Musings on telepresence and virtual presence," *Presence: Teleoperators and Virtual Environments*, 1, pp. 120-125, 1992.

[SIMO 99] Simons, R., Detenber, B., Roedema, T., Reiss, J., "Emotion processing in three systems: The medium and the message," *Psychophysiology*, 36, pp. 619-627, 1999.

[SING 96] Singer, M.J., & Witmer, B.G., "Presence measures for virtual environments: Background and development," *Draft United States Army Research Institute Research Note*, 1996.

[SLAT 95] Slater, M., Usoh, M., and Steed, A., "Taking steps: The influence of a walking technique on presence in virtual reality," *ACM Transactions on Computer-Human Interaction,* 2(3), pp. 201-219, September 1995.

[SLAT 98] Slater, M., Steed, A., McCarthy, J. & Maringelli, F., “The influence of body movement on subjective presence in virtual environments,” *Human Factors,* 40(3), pp. 469-477, 1998.

[SLAT 99] Slater, M., “Measuring presence: A response to the Witmer and Singer Presence Questionnaire,” *Presence: Teleoperators and Virtual Environments,* 8(5), pp. 560-565, 1999.

[SMIT 84] Smith, T. W., Houston, B. K., and Zurawski, R.M., “Finger Pulse Volume as a measure fo anxiety in response to evaluative threat,” *Psychophysiology*, 21(3), pp. 260-264, 1984.

[SNOW 98] Snow, M.P. & Williges, R.C., “Empirical models based on free-modulus magnitude estimation of perceived presence in virtual environments,” *Human Factors,* 40, pp. 386-402, 1998.

[USOH 00] Usoh, M., Catena, E., Arma, S., Slater, M., “Using presence questionnaires in reality,” *Presence: Teleoperators and Virtual Environments*, 9(5), pp. 497-503, 2000.

[VINC 01] Vince, J., *Essential Virtual Reality Fast*, 3rd ed., Springer-Verlag, 2001.

[VYZA 98] M.I.T. Media Laboratory Perceptual Computing Section Technical Report No. 473, *Affective Pattern Classification*, by E. Vyzas, and R. Picard, 1998.

[WEBS 88] “Webster’s II New Riverside University Dictionary,” 2d ed., The Riverside Publishing Company, 1988.

[WEBS 88a] “New World Dictionary of American English,” 3d ed., Simon and Schuster, Inc., 1988.

[WITM 98] Witmer, B.G. & Singer, M.J., "Measuring presence in virtual environments: A presence questionnaire." *Presence: Teleoperators and Virtual Environments,* 7, pp. 225-240, 1998.

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APPENDIX A. RAW DATA

Condition	ID	BLEDA	BLTEMP	BLHR	CEDA	CTEMP	CHR	DEDA	DTEMP	DHR	QEDA	QTEMP	QHR	Sleep	Caffein	Gaming	Gender
No Sound	1	1.03	72.72	54.47	0.97	70.45	59.06	-0.06	-2.27	4.59	0.94	0.97	1.08	4	1	1	1
No Sound	29	0.67	90.24	71.78	1.08	89.21	69.14	0.41	-1.03	-2.64	1.61	0.99	0.96	3	3	2	1
No Sound	33	1.66	80.86	67.90	1.76	77.76	71.62	0.10	-3.10	3.72	1.06	0.96	1.05	3	3	3	1
No Sound	35	0.38	88.65	73.18	0.30	87.81	76.84	-0.08	-0.84	3.66	0.79	0.99	1.05	3	1	1	1
No Sound	41	0.70	72.77	69.00	1.57	72.43	73.55	0.87	-0.34	4.55	2.24	1.00	1.07	1	5	1	2
No Sound	43	0.78	85.65	72.80	1.06	81.44	74.49	0.28	-4.21	1.69	1.36	0.95	1.02	4	3	2	1
No Sound	49	0.46	79.14	60.44	0.92	75.99	64.68	0.46	-3.15	4.24	2.00	0.96	1.07	4	3	2	1
No Sound	54	0.71	91.03	77.07	1.27	92.50	76.20	0.56	1.47	-0.87	1.79	1.02	0.99	4	1	2	1
No Sound	58	0.18	76.27	49.91	0.21	74.66	50.58	0.03	-1.61	0.67	1.17	0.98	1.01	4	1	2	1
No Sound	60	2.56	89.18	76.70	5.70	90.82	74.41	3.14	1.64	-2.29	2.23	1.02	0.97	4	2	2	1
No Sound	62	0.86	76.99	65.61	1.19	74.95	67.90	0.33	-2.04	2.29	1.38	0.97	1.03	4	4	2	1
No Sound	64	2.00	89.68	70.07	2.73	92.58	72.16	0.73	2.90	2.09	1.37	1.03	1.03	3	1	3	1
No Sound	69	0.93	87.85	81.87	1.60	89.35	88.06	0.67	1.50	6.19	1.72	1.02	1.08	3	4	5	1
No Sound	70	3.43	88.27	62.95	5.36	88.78	63.65	1.93	0.51	0.70	1.56	1.01	1.01	4	4	2	1
No Sound	73	0.61	90.88	62.04	0.57	90.20	63.04	-0.04	-0.68	1.00	0.93	0.99	1.02	2	4	1	1
No Sound	76	4.33	90.55	85.54	6.81	90.78	83.64	2.48	0.23	-1.90	1.57	1.00	0.98	4	2	3	1
No Sound	78	0.87	73.02	84.86	0.95	72.62	113.72	0.08	-0.40	28.86	1.09	0.99	1.34	3	3	2	1
No Sound	88	1.15	73.91	71.77	1.34	73.06	72.47	0.19	-0.85	0.70	1.17	0.99	1.01	3	1	3	1
No Sound	93	0.31	91.91	75.03	0.41	92.08	79.56	0.10	0.17	4.53	1.32	1.00	1.06	4	5	2	1
No Sound	97	1.32	85.87	69.68	1.88	85.90	68.05	0.56	0.03	-1.63	1.42	1.00	0.98	4	4	1	1
Speakers	5	2.84	76.56	73.44	3.69	73.82	79.05	0.85	-2.74	5.61	1.30	0.96	1.08	3	3	2	1
Speakers	6	0.91	82.10	79.88	1.67	77.93	96.40	0.76	-4.17	16.52	1.84	0.95	1.21	4	1	3	1
Speakers	26	0.90	86.09	70.44	1.34	81.13	72.67	0.44	-4.96	2.23	1.49	0.94	1.03	4	1	2	1
Speakers	30	3.70	85.37	75.87	6.02	82.55	80.62	2.32	-2.82	4.75	1.63	0.97	1.06	4	4	1	1
Speakers	31	0.11	77.10	63.76	0.15	75.52	69.80	0.04	-1.58	6.04	1.36	0.98	1.09	3	1	2	1
Speakers	36	1.37	75.93	96.61	1.87	73.08	93.26	0.50	-2.85	-3.35	1.36	0.96	0.97	3	1	1	2
Speakers	40	0.99	91.07	79.96	1.59	88.81	82.17	0.60	-2.26	2.21	1.61	0.98	1.03	4	3	1	1
Speakers	44	2.28	86.26	92.49	3.04	81.72	94.67	0.76	-4.54	2.18	1.33	0.95	1.02	4	1	2	1
Speakers	46	0.50	84.11	69.97	1.03	80.40	73.47	0.53	-3.71	3.50	2.06	0.96	1.05	4	4	4	1
Speakers	47	0.45	79.59	43.93	1.18	76.34	52.13	0.73	-3.25	8.20	2.62	0.96	1.19	4	1	2	1
Speakers	52	4.53	83.67	66.42	7.50	80.57	79.66	2.97	-3.10	13.24	1.66	0.96	1.20	3	2	2	1
Speakers	56	0.95	70.72	89.48	1.80	69.91	80.11	0.85	-0.81	-9.37	1.89	0.99	0.90	4	1	2	1
Speakers	59	1.37	89.70	66.59	2.83	86.32	75.69	1.46	-3.38	9.10	2.07	0.96	1.14	4	1	2	1
Speakers	63	1.29	84.54	69.70	2.49	80.78	68.59	1.20	-3.76	-1.11	1.93	0.96	0.98	3	1	3	1
Speakers	71	1.49	86.70	73.63	2.07	80.32	73.36	0.58	-6.38	-0.27	1.39	0.93	1.00	3	4	1	1
Speakers	77	0.74	90.40	66.18	3.69	86.78	66.50	2.95	-3.62	0.32	4.99	0.96	1.00	3	1	3	1
Speakers	82	0.64	90.61	81.22	1.31	88.94	94.30	0.67	-1.67	13.08	2.05	0.98	1.16	4	3	4	1
Speakers	89	6.54	84.32	74.75	8.92	78.68	86.28	2.38	-5.64	11.53	1.36	0.93	1.15	3	3	3	1
Speakers	91	1.38	90.00	79.53	1.92	86.05	88.65	0.54	-3.95	9.12	1.39	0.96	1.11	3	5	4	1
Speakers	95	0.71	88.89	79.14	0.93	86.93	80.44	0.22	-1.96	1.30	1.31	0.98	1.02	5	1	2	1
Headphones	2	0.50	73.41	65.02	0.78	71.56	65.67	0.28	-1.85	0.65	1.56	0.97	1.01	3	3	3	1
Headphones	25	1.25	78.27	61.66	3.57	77.73	74.62	2.32	-0.54	12.96	2.86	0.99	1.21	3	3	4	1
Headphones	42	1.32	85.39	70.38	2.12	83.20	75.09	0.80	-2.19	4.71	1.61	0.97	1.07	4	4	3	1
Headphones	50	1.44	84.16	60.41	1.77	80.67	60.74	0.33	-3.49	0.33	1.23	0.96	1.01	4	3	2	1
Headphones	51	1.38	71.40	80.94	3.33	71.28	87.38	1.95	-0.12	6.44	2.41	1.00	1.08	4	1	3	1
Headphones	55	4.74	93.00	75.45	11.32	90.76	74.77	6.58	-2.24	-0.68	2.39	0.98	0.99	3	5	5	1
Headphones	57	1.91	74.60	76.24	4.43	74.18	81.69	2.52	-0.42	5.45	2.32	0.99	1.07	4	4	2	1
Headphones	65	0.43	77.87	93.39	0.58	76.38	103.65	0.15	-1.49	10.26	1.35	0.98	1.11	4	3	2	2
Headphones	67	0.81	85.40	69.57	1.62	79.51	71.66	0.81	-5.89	2.09	2.00	0.93	1.03	3	5	2	1
Headphones	68	1.02	87.15	71.01	1.58	85.47	79.48	0.56	-1.68	8.47	1.55	0.98	1.12	4	2	5	1
Headphones	72	1.41	93.84	82.17	2.13	93.81	79.29	0.72	-0.03	-2.88	1.51	1.00	0.96	3	5	2	1
Headphones	75	1.36	93.88	77.35	2.53	92.88	85.10	1.17	-1.00	7.75	1.86	0.99	1.10	4	5	2	1
Headphones	79	0.99	91.11	67.93	1.42	89.73	69.81	0.43	-1.38	1.88	1.43	0.98	1.03	4	1	1	1
Headphones	80	1.54	80.76	64.69	2.07	76.94	67.99	0.53	-3.82	3.30	1.34	0.95	1.05	4	2	1	1
Headphones	81	1.82	89.46	84.19	2.72	91.12	86.57	0.90	1.66	2.38	1.49	1.02	1.03	4	4	1	1
Headphones	84	1.31	90.42	86.65	2.33	89.96	84.69	1.02	-0.46	-1.96	1.78	0.99	0.98	3	2	3	1
Headphones	85	0.94	92.62	95.58	2.23	92.77	96.00	1.29	0.15	0.42	2.37	1.00	1.00	4	1	2	1
Headphones	86	0.64	88.53	74.63	0.89	83.69	85.43	0.25	-4.84	10.80	1.39	0.95	1.14	3	3	2	1
Headphones	90	0.97	92.49	77.52	2.29	91.36	74.37	1.32	-1.13	-3.15	2.36	0.99	0.96	3	1	1	1
Headphones	96	1.93	81.99	47.34	2.23	78.70	48.42	0.30	-3.29	1.08	1.16	0.96	1.02	4	1	2	1
HP w/Subwoofer	3	0.76	67.47	63.63	1.08	67.74	61.59	0.32	0.27	-2.04	1.42	1.00	0.97	4	5	3	1
HP w/Subwoofer	4	0.68	77.03	77.01	0.67	74.56	74.40	-0.01	-2.47	-2.61	0.99	0.97	0.97	3	1	2	1
HP w/Subwoofer	24	0.58	86.14	64.70	1.11	81.51	65.33	0.53	-4.63	0.63	1.91	0.95	1.01	4	1	1	1
HP w/Subwoofer	27	0.25	79.31	69.80	1.64	73.24	69.83	1.39	-6.07	0.03	6.56	0.92	1.00	2	1	2	1
HP w/Subwoofer	28	2.31	87.35	58.13	2.86	83.13	59.37	0.55	-4.22	1.24	1.24	0.95	1.02	3	1	4	1
HP w/Subwoofer	32	0.66	81.89	67.11	0.75	77.70	65.15	0.09	-4.19	-1.96	1.14	0.95	0.97	3	5	1	2
HP w/Subwoofer	34	3.02	87.54	78.70	10.57	90.09	91.42	7.55	2.55	12.72	3.50	1.03	1.16	3	3	2	1
HP w/Subwoofer	37	0.76	85.97	56.66	1.62	80.34	59.03	0.86	-5.63	2.37	2.13	0.93	1.04	4	1	1	1
HP w/Subwoofer	38	0.84	87.23	59.55	1.97	83.02	63.52	1.13	-4.21	3.97	2.35	0.95	1.07	4	3	4	1
HP w/Subwoofer	39	0.61	78.81	58.68	0.93	75.67	61.58	0.32	-3.14	2.90	1.52	0.96	1.05	4	4	2	1
HP w/Subwoofer	45	2.33	75.94	77.41	3.49	74.68	82.48	1.16	-1.26	5.07	1.50	0.98	1.07	4	5	4	1
HP w/Subwoofer	48	1.52	81.74	62.75	3.35	81.62	65.07	1.83	-0.12	2.32	2.20	1.00	1.04	3	2	2	1
HP w/Subwoofer	53	0.58	75.40	67.04	1.01	73.99	80.78	0.43	-1.41	13.74	1.74	0.98	1.20	4	1	4	1
HP w/Subwoofer	61	1.60	77.34	67.85	1.79	74.51	82.65	0.19	-2.83	14.80	1.12	0.96	1.22	3	1	1	1
HP w/Subwoofer	66	1.82	75.14	78.91	1.12	73.59	80.73	-0.70	-1.55	1.82	0.62	0.98	1.02	4	2	2	1
HP w/Subwoofer	74	0.40	94.57	78.79	1.02	95.05	75.79	0.62	0.48	-3.00	2.55	1.01	0.96	4	3	1	1
HP w/Subwoofer	83	0.92	77.04	68.92	2.04	75.37	72.97	1.12	-1.67	4.05	2.22	0.98	1.06	5	1	4	1
HP w/Subwoofer	87	0.79	84.89	82.33	1.54	80.55	85.84	0.75	-4.34	3.51	1.95	0.95	1.04	3	2	2	1
HP w/Subwoofer	92	1.86	81.74	53.31	3.51	78.65	68.07	1.65	-3.09	14.76	1.89	0.96	1.28	4	3	3	1
HP w/Subwoofer	94	1.49	92.12	79.52	1.78	92.62	79.99	0.29	0.50	0.47	1.19	1.01	1.01	4	4	1	1

Age	Hearing	Level	Medical	Concern	Movies	TvBook	Alert	MovAwar	Charact	VidGame	FitToda	BlockOu	WatcGam	DayDrea	Dreams	Sports	Concent
5	2	99.00	2	99.00	2.00	2.00	4.00	1.00	3.00	1.00	6.00	3.00	1.00	1.00	1.00	2.00	4.00
4	2	99.00	2	99.00	4.00	4.00	5.00	3.00	3.00	3.00	5.00	5.00	5.00	2.00	2.00	5.00	5.00
3	2	99.00	2	99.00	4.00	3.00	3.00	4.00	5.00	5.00	5.00	3.00	3.00	6.00	1.00	3.00	4.00
4	2	99.00	2	99.00	4.00	6.00	5.00	6.00	2.00	1.00	6.00	5.00	2.00	4.00	1.00	5.00	4.00
4	2	99.00	2	99.00	4.00	3.00	6.00	2.00	3.00	2.00	5.00	6.00	2.00	3.00	4.00	4.00	4.00
5	2	99.00	2	99.00	4.00	4.00	5.00	4.00	4.00	1.00	4.00	5.00	3.00	3.00	2.00	4.00	5.00
3	2	99.00	2	99.00	6.00	4.00	4.00	3.00	3.00	6.00	5.00	6.00	3.00	5.00	6.00	6.00	7.00
2	2	99.00	2	99.00	4.00	4.00	4.00	4.00	5.00	5.00	5.00	4.00	5.00	5.00	5.00	5.00	5.00
4	2	99.00	2	99.00	3.00	4.00	6.00	2.00	2.00	1.00	5.00	4.00	1.00	3.00	2.00	4.00	4.00
2	2	99.00	2	99.00	5.00	6.00	6.00	6.00	4.00	4.00	5.00	5.00	3.00	5.00	5.00	2.00	5.00
5	2	99.00	2	99.00	6.00	5.00	7.00	4.00	6.00	3.00	5.00	4.00	2.00	2.00	1.00	4.00	6.00
4	2	99.00	2	99.00	5.00	6.00	5.00	5.00	5.00	6.00	4.00	7.00	5.00	6.00	4.00	6.00	7.00
2	2	99.00	2	99.00	6.00	7.00	4.00	5.00	6.00	6.00	3.00	4.00	4.00	4.00	5.00	4.00	7.00
3	2	99.00	2	99.00	4.00	4.00	7.00	4.00	4.00	2.00	7.00	6.00	5.00	2.00	4.00	5.00	7.00
4	2	99.00	2	99.00	2.00	2.00	3.00	2.00	2.00	2.00	4.00	2.00	1.00	1.00	1.00	5.00	6.00
5	1	4.00	2	99.00	6.00	5.00	6.00	4.00	5.00	5.00	6.00	7.00	6.00	5.00	5.00	7.00	7.00
1	2	99.00	2	99.00	7.00	7.00	1.00	7.00	7.00	7.00	1.00	6.00	1.00	7.00	7.00	1.00	7.00
3	2	99.00	2	99.00	4.00	6.00	4.00	4.00	3.00	1.00	4.00	4.00	4.00	4.00	3.00	6.00	7.00
4	2	99.00	2	99.00	4.00	4.00	5.00	5.00	4.00	4.00	5.00	5.00	5.00	4.00	2.00	5.00	6.00
3	2	99.00	2	99.00	3.00	4.00	5.00	3.00	4.00	2.00	5.00	6.00	4.00	4.00	4.00	5.00	5.00
4	2	99.00	2	99.00	5.00	5.00	4.00	5.00	5.00	4.00	6.00	6.00	7.00	5.00	4.00	7.00	6.00
4	2	99.00	2	99.00	5.00	4.00	7.00	4.00	4.00	4.00	5.00	4.00	3.00	5.00	4.00	5.00	7.00
3	2	99.00	2	99.00	5.00	5.00	6.00	5.00	4.00	3.00	6.00	5.00	5.00	3.00	5.00	6.00	7.00
5	2	99.00	2	99.00	3.00	4.00	4.00	5.00	3.00	2.00	2.00	3.00	6.00	3.00	2.00	6.00	3.00
4	2	99.00	2	99.00	4.00	4.00	6.00	3.00	1.00	2.00	4.00	5.00	2.00	2.00	2.00	4.00	5.00
5	2	99.00	2	99.00	6.00	6.00	4.00	6.00	6.00	6.00	4.00	3.00	4.00	4.00	4.00	4.00	6.00
3	2	99.00	2	99.00	4.00	4.00	1.00	4.00	4.00	3.00	4.00	5.00	4.00	2.00	4.00	4.00	7.00
2	2	99.00	2	99.00	5.00	4.00	4.00	4.00	3.00	4.00	3.00	6.00	4.00	2.00	1.00	2.00	4.00
2	2	99.00	2	99.00	5.00	3.00	6.00	4.00	4.00	5.00	4.00	5.00	3.00	4.00	5.00	5.00	6.00
5	2	99.00	2	99.00	5.00	3.00	6.00	4.00	4.00	1.00	6.00	5.00	5.00	3.00	3.00	4.00	6.00
2	2	99.00	2	99.00	4.00	2.00	6.00	3.00	5.00	2.00	6.00	4.00	3.00	2.00	2.00	6.00	6.00
3	2	99.00	2	99.00	4.00	4.00	6.00	5.00	5.00	6.00	4.00	7.00	4.00	3.00	4.00	6.00	7.00
3	2	99.00	2	99.00	5.00	6.00	7.00	5.00	6.00	4.00	5.00	5.00	3.00	6.00	3.00	5.00	7.00
4	2	99.00	2	99.00	4.00	4.00	7.00	4.00	4.00	4.00	5.00	6.00	6.00	4.00	5.00	6.00	6.00
4	2	99.00	2	99.00	4.00	1.00	7.00	4.00	5.00	3.00	4.00	4.00	6.00	2.00	2.00	6.00	6.00
4	2	99.00	2	99.00	5.00	5.00	5.00	5.00	4.00	5.00	3.00	6.00	6.00	3.00	3.00	6.00	7.00
2	2	99.00	2	99.00	5.00	4.00	6.00	4.00	4.00	4.00	5.00	5.00	3.00	5.00	5.00	5.00	7.00
3	2	99.00	2	99.00	7.00	4.00	6.00	4.00	4.00	3.00	5.00	6.00	3.00	4.00	2.00	4.00	7.00
4	2	99.00	2	99.00	2.00	3.00	5.00	3.00	2.00	1.00	4.00	6.00	1.00	3.00	5.00	1.00	6.00
4	2	99.00	2	99.00	4.00	2.00	4.00	2.00	4.00	3.00	4.00	5.00	2.00	3.00	5.00	5.00	5.00
3	2	99.00	2	99.00	6.00	4.00	6.00	6.00	4.00	5.00	6.00	5.00	4.00	4.00	3.00	6.00	6.00
2	1	1.00	2	99.00	4.00	4.00	7.00	6.00	3.00	4.00	6.00	7.00	4.00	3.00	1.00	4.00	6.00
4	2	99.00	2	99.00	5.00	5.00	6.00	4.00	5.00	6.00	5.00	6.00	5.00	3.00	2.00	6.00	5.00
4	2	99.00	2	99.00	5.00	6.00	7.00	4.00	4.00	4.00	6.00	7.00	5.00	4.00	4.00	5.00	7.00
1	2	99.00	2	99.00	4.00	5.00	5.00	5.00	5.00	5.00	5.00	6.00	2.00	5.00	5.00	6.00	6.00
2	2	99.00	2	99.00	6.00	4.00	7.00	4.00	5.00	6.00	6.00	7.00	5.00	5.00	4.00	3.00	7.00
4	1	4.00	2	99.00	7.00	7.00	4.00	6.00	4.00	2.00	4.00	4.00	4.00	5.00	5.00	6.00	7.00
2	2	99.00	2	99.00	2.00	6.00	6.00	4.00	2.00	4.00	6.00	5.00	2.00	6.00	4.00	4.00	7.00
3	2	99.00	2	99.00	5.00	3.00	4.00	4.00	2.00	2.00	5.00	5.00	3.00	5.00	3.00	4.00	7.00
2	2	99.00	2	99.00	4.00	7.00	7.00	5.00	4.00	7.00	4.00	7.00	2.00	2.00	5.00	5.00	7.00
2	2	99.00	2	99.00	4.00	5.00	5.00	4.00	4.00	5.00	5.00	6.00	4.00	5.00	3.00	5.00	6.00
5	2	99.00	2	99.00	6.00	5.00	7.00	5.00	4.00	2.00	5.00	5.00	4.00	4.00	2.00	5.00	6.00
2	2	99.00	2	99.00	5.00	3.00	5.00	4.00	1.00	1.00	6.00	7.00	2.00	2.00	4.00	6.00	4.00
3	2	99.00	2	99.00	5.00	5.00	6.00	5.00	3.00	1.00	4.00	2.00	1.00	4.00	3.00	2.00	6.00
5	2	99.00	2	99.00	4.00	4.00	6.00	4.00	4.00	1.00	6.00	6.00	5.00	3.00	4.00	5.00	6.00
3	2	99.00	2	99.00	4.00	5.00	5.00	6.00	5.00	6.00	5.00	6.00	4.00	4.00	4.00	6.00	6.00
5	2	99.00	2	99.00	4.00	4.00	3.00	4.00	4.00	4.00	3.00	3.00	3.00	4.00	3.00	4.00	5.00
4	1	2.00	2	99.00	4.00	4.00	4.00	3.00	3.00	3.00	5.00	5.00	5.00	1.00	3.00	6.00	5.00
3	2	99.00	2	99.00	6.00	2.00	5.00	2.00	4.00	1.00	4.00	5.00	4.00	3.00	4.00	5.00	5.00
2	2	99.00	2	99.00	2.00	3.00	4.00	2.00	2.00	3.00	5.00	4.00	5.00	1.00	2.00	6.00	5.00
4	2	99.00	2	99.00	6.00	5.00	7.00	5.00	6.00	5.00	6.00	6.00	6.00	3.00	4.00	4.00	7.00
2	2	99.00	2	99.00	3.00	2.00	5.00	1.00	2.00	1.00	6.00	4.00	1.00	1.00	3.00	5.00	6.00
3	2	99.00	2	99.00	1.00	2.00	6.00	4.00	4.00	2.00	6.00	6.00	4.00	4.00	2.00	4.00	6.00
3	2	99.00	2	99.00	3.00	2.00	4.00	2.00	4.00	3.00	5.00	6.00	4.00	2.00	3.00	7.00	7.00
2	2	99.00	2	99.00	5.00	3.00	6.00	5.00	5.00	4.00	6.00	4.00	5.00	4.00	3.00	5.00	6.00
3	2	99.00	2	99.00	5.00	4.00	4.00	4.00	6.00	1.00	3.00	5.00	1.00	6.00	5.00	2.00	5.00
5	2	99.00	2	99.00	7.00	7.00	5.00	7.00	7.00	7.00	4.00	6.00	6.00	6.00	4.00	6.00	6.00
5	2	99.00	2	99.00	4.00	2.00	5.00	1.00	2.00	1.00	5.00	5.00	2.00	2.00	1.00	6.00	6.00
3	2	99.00	2	99.00	4.00	5.00	7.00	6.00	4.00	2.00	5.00	5.00	2.00	2.00	4.00	4.00	6.00
4	2	99.00	2	99.00	2.00	1.00	4.00	1.00	3.00	2.00	4.00	4.00	1.00	1.00	2.00	2.00	5.00
2	2	99.00	2	99.00	6.00	3.00	5.00	5.00	5.00	5.00	5.00	4.00	4.00	4.00	5.00	7.00	7.00
3	2	99.00	2	99.00	2.00	2.00	5.00	2.00	2.00	2.00	6.00	4.00	2.00	2.00	2.00	2.00	3.00
2	2	99.00	2	99.00	4.00	4.00	4.00	4.00	4.00	3.00	5.00	5.00	2.00	2.00	5.00	4.00	5.00
3	2	99.00	2	99.00	1.00	4.00	4.00	4.00	2.00	3.00	3.00	4.00	6.00	2.00	4.00	2.00	5.00
2	2	99.00	2	99.00	5.00	4.00	4.00	5.00	6.00	6.00	5.00	4.00	5.00	3.00	4.00	5.00	6.00
5	2	99.00	2	99.00	2.00	4.00	7.00	1.00	1.00	1.00	5.00	7.00	4.00	4.00	1.00	6.00	6.00
2	2	99.00	2	99.00	4.00	3.00	5.00	4.00	3.00	5.00	3.00	7.00	2.00	6.00	4.00	4.00	6.00
4	2	99.00	2	99.00	5.00	3.00	7.00	1.00	3.00	2.00	6.00	6.00	5.00	2.00	3.00	5.00	6.00
3	2	99.00	2	99.00	6.00	7.00	5.00	7.00	4.00	2.00	6.00	2.00	2.00	1.00	4.00	4.00	5.00
5	2	99.00	2	99.00	1.00	4.00	7.00	1.00	1.00	1.00	4.00	4.00	1.00	1.00	1.00	1.00	4.00

PlayVG	TvFight	Scared	Fearful	LosTack	ITQ.Total	Control	Res	Natural	VisAsp	Slate5	AudAsp	Mechani	SensObj	Slate3	Consist	Slate6	ResAct
1.00	4.00	2.00	2.00	3.00	43.00	2.00	2.00	3.00	5.00	4.00	1.00	3.00	3.00	2.00	3.00	6.00	2.00
2.00	5.00	5.00	2.00	1.00	66.00	5.00	3.00	3.00	4.00	3.00	1.00	2.00	2.00	1.00	1.00	1.00	6.00
3.00	3.00	2.00	4.00	5.00	66.00	6.00	6.00	5.00	6.00	5.00	1.00	3.00	4.00	4.00	3.00	4.00	5.00
2.00	3.00	2.00	2.00	4.00	64.00	5.00	6.00	3.00	5.00	3.00	1.00	3.00	2.00	2.00	6.00	1.00	1.00
1.00	7.00	7.00	6.00	4.00	73.00	5.00	7.00	6.00	7.00	6.00	1.00	5.00	7.00	6.00	6.00	6.00	6.00
1.00	4.00	4.00	3.00	4.00	64.00	5.00	6.00	5.00	5.00	1.00	1.00	5.00	5.00	4.00	4.00	5.00	5.00
2.00	6.00	4.00	5.00	6.00	87.00	5.00	6.00	5.00	6.00	3.00	4.00	3.00	5.00	6.00	4.00	5.00	5.00
5.00	4.00	6.00	4.00	5.00	84.00	3.00	3.00	2.00	4.00	3.00	1.00	2.00	4.00	3.00	3.00	4.00	3.00
4.00	3.00	2.00	2.00	3.00	55.00	2.00	4.00	3.00	4.00	3.00	1.00	3.00	3.00	2.00	6.00	2.00	4.00
6.00	4.00	3.00	3.00	5.00	82.00	6.00	6.00	5.00	5.00	4.00	1.00	5.00	6.00	6.00	4.00	3.00	4.00
3.00	2.00	2.00	1.00	2.00	65.00	3.00	6.00	5.00	7.00	6.00	6.00	4.00	5.00	4.00	2.00	6.00	6.00
3.00	4.00	3.00	3.00	5.00	89.00	5.00	6.00	4.00	5.00	7.00	3.00	3.00	6.00	6.00	4.00	4.00	5.00
7.00	6.00	4.00	2.00	4.00	88.00	5.00	7.00	5.00	6.00	4.00	1.00	5.00	6.00	6.00	3.00	5.00	6.00
2.00	6.00	3.00	1.00	2.00	75.00	4.00	3.00	2.00	4.00	5.00	1.00	1.00	6.00	3.00	5.00	2.00	5.00
1.00	2.00	2.00	2.00	2.00	42.00	2.00	4.00	2.00	4.00	1.00	1.00	2.00	2.00	2.00	6.00	1.00	2.00
4.00	6.00	5.00	4.00	7.00	100.00	3.00	6.00	4.00	6.00	6.00	5.00	5.00	5.00	5.00	3.00	4.00	4.00
3.00	7.00	4.00	2.00	7.00	89.00	2.00	4.00	3.00	5.00	5.00	1.00	4.00	6.00	3.00	4.00	3.00	2.00
3.00	4.00	4.00	3.00	7.00	75.00	4.00	4.00	4.00	4.00	2.00	1.00	3.00	4.00	3.00	3.00	4.00	4.00
4.00	5.00	5.00	4.00	4.00	80.00	3.00	5.00	4.00	4.00	3.00	1.00	3.00	5.00	4.00	2.00	2.00	5.00
2.00	3.00	5.00	4.00	4.00	72.00	3.00	4.00	4.00	5.00	6.00	5.00	4.00	3.00	3.00	4.00	2.00	3.00
2.00	4.00	4.00	2.00	6.00	87.00	4.00	6.00	5.00	6.00	5.00	7.00	4.00	5.00	6.00	6.00	2.00	5.00
3.00	4.00	5.00	5.00	5.00	83.00	5.00	5.00	4.00	5.00	5.00	6.00	3.00	4.00	6.00	3.00	4.00	5.00
5.00	6.00	2.00	1.00	5.00	84.00	2.00	4.00	5.00	6.00	6.00	5.00	4.00	5.00	3.00	5.00	4.00	4.00
2.00	4.00	3.00	3.00	2.00	60.00	3.00	5.00	5.00	5.00	6.00	3.00	2.00	3.00	4.00	2.00	2.00	6.00
5.00	4.00	3.00	1.00	3.00	60.00	3.00	4.00	4.00	5.00	3.00	4.00	2.00	4.00	3.00	6.00	3.00	3.00
1.00	5.00	7.00	7.00	7.00	90.00	4.00	5.00	4.00	6.00	6.00	5.00	4.00	6.00	6.00	4.00	5.00	4.00
2.00	4.00	4.00	1.00	7.00	68.00	1.00	2.00	1.00	4.00	4.00	5.00	5.00	3.00	4.00	4.00	7.00	4.00
3.00	4.00	3.00	3.00	6.00	65.00	3.00	6.00	6.00	5.00	2.00	7.00	6.00	5.00	6.00	3.00	4.00	5.00
6.00	6.00	6.00	6.00	6.00	89.00	4.00	5.00	5.00	4.00	6.00	6.00	6.00	6.00	5.00	2.00	6.00	5.00
2.00	5.00	5.00	2.00	3.00	72.00	4.00	6.00	6.00	7.00	5.00	7.00	6.00	6.00	6.00	2.00	5.00	5.00
5.00	4.00	4.00	2.00	5.00	71.00	5.00	6.00	6.00	5.00	5.00	6.00	5.00	6.00	3.00	5.00	2.00	5.00
6.00	4.00	2.00	1.00	5.00	83.00	4.00	6.00	2.00	4.00	5.00	5.00	2.00	4.00	3.00	4.00	3.00	4.00
4.00	6.00	6.00	2.00	5.00	90.00	6.00	4.00	3.00	5.00	6.00	5.00	4.00	5.00	5.00	4.00	4.00	4.00
4.00	4.00	4.00	4.00	6.00	87.00	4.00	5.00	5.00	6.00	5.00	6.00	4.00	5.00	3.00	4.00	2.00	4.00
2.00	4.00	4.00	2.00	5.00	71.00	4.00	4.00	2.00	4.00	4.00	5.00	2.00	5.00	4.00	6.00	1.00	2.00
4.00	5.00	3.00	3.00	6.00	84.00	5.00	4.00	5.00	6.00	4.00	5.00	4.00	5.00	5.00	3.00	5.00	5.00
7.00	5.00	3.00	3.00	5.00	85.00	6.00	6.00	6.00	6.00	5.00	7.00	6.00	6.00	5.00	5.00	5.00	6.00
3.00	6.00	4.00	2.00	4.00	78.00	4.00	6.00	6.00	7.00	6.00	7.00	4.00	5.00	5.00	3.00	5.00	5.00
4.00	4.00	5.00	2.00	5.00	62.00	4.00	5.00	5.00	6.00	4.00	6.00	4.00	5.00	5.00	4.00	3.00	2.00
4.00	3.00	5.00	4.00	4.00	68.00	3.00	6.00	5.00	5.00	6.00	6.00	4.00	5.00	5.00	4.00	2.00	5.00
4.00	5.00	5.00	4.00	5.00	88.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	3.00	3.00	3.00	4.00
7.00	6.00	2.00	1.00	2.00	77.00	6.00	5.00	4.00	7.00	3.00	5.00	2.00	5.00	6.00	5.00	3.00	7.00
2.00	7.00	6.00	2.00	4.00	84.00	2.00	5.00	4.00	5.00	5.00	6.00	5.00	5.00	4.00	1.00	5.00	4.00
2.00	3.00	3.00	2.00	5.00	83.00	6.00	6.00	5.00	6.00	7.00	6.00	6.00	6.00	5.00	4.00	4.00	6.00
7.00	5.00	5.00	3.00	5.00	89.00	5.00	2.00	4.00	5.00	6.00	5.00	4.00	5.00	5.00	5.00	4.00	5.00
7.00	7.00	5.00	3.00	6.00	97.00	7.00	7.00	5.00	6.00	4.00	7.00	5.00	5.00	3.00	4.00	4.00	6.00
2.00	6.00	4.00	3.00	5.00	85.00	3.00	3.00	6.00	6.00	4.00	5.00	5.00	6.00	4.00	3.00	4.00	4.00
4.00	4.00	6.00	4.00	5.00	81.00	4.00	5.00	3.00	6.00	3.00	6.00	4.00	5.00	4.00	5.00	4.00	4.00
3.00	5.00	5.00	4.00	3.00	72.00	3.00	4.00	5.00	6.00	4.00	7.00	2.00	5.00	5.00	5.00	5.00	4.00
7.00	7.00	7.00	4.00	7.00	98.00	6.00	5.00	7.00	7.00	6.00	7.00	4.00	6.00	6.00	3.00	6.00	5.00
2.00	3.00	4.00	2.00	6.00	78.00	4.00	5.00	5.00	5.00	6.00	6.00	2.00	5.00	4.00	2.00	4.00	5.00
2.00	5.00	4.00	2.00	5.00	78.00	4.00	6.00	4.00	6.00	6.00	6.00	2.00	6.00	4.00	3.00	3.00	4.00
1.00	7.00	2.00	1.00	5.00	66.00	3.00	2.00	3.00	4.00	4.00	6.00	4.00	4.00	3.00	5.00	3.00	5.00
1.00	5.00	5.00	4.00	2.00	64.00	4.00	5.00	5.00	5.00	1.00	6.00	4.00	4.00	1.00	1.00	2.00	6.00
1.00	4.00	1.00	1.00	5.00	70.00	2.00	6.00	5.00	5.00	5.00	5.00	4.00	5.00	1.00	4.00	1.00	4.00
3.00	4.00	3.00	2.00	6.00	84.00	3.00	3.00	3.00	5.00	6.00	6.00	4.00	3.00	5.00	5.00	5.00	4.00
2.00	4.00	4.00	2.00	4.00	64.00	3.00	6.00	3.00	6.00	5.00	6.00	2.00	5.00	3.00	4.00	4.00	3.00
2.00	4.00	4.00	3.00	4.00	68.00	5.00	5.00	5.00	5.00	5.00	6.00	4.00	6.00	5.00	5.00	4.00	4.00
2.00	3.00	4.00	1.00	3.00	63.00	3.00	5.00	5.00	5.00	5.00	4.00	4.00	4.00	4.00	3.00	4.00	3.00
2.00	3.00	3.00	2.00	6.00	60.00	2.00	4.00	4.00	4.00	5.00	3.00	4.00	3.00	3.00	4.00	3.00	3.00
5.00	5.00	6.00	5.00	4.00	95.00	5.00	6.00	5.00	6.00	6.00	6.00	5.00	6.00	6.00	6.00	2.00	6.00
2.00	2.00	2.00	1.00	1.00	48.00	4.00	5.00	4.00	5.00	4.00	6.00	3.00	4.00	2.00	3.00	6.00	5.00
1.00	4.00	1.00	1.00	4.00	62.00	4.00	6.00	4.00	5.00	4.00	6.00	3.00	2.00	2.00	3.00	2.00	4.00
2.00	5.00	2.00	1.00	5.00	67.00	4.00	4.00	4.00	5.00	5.00	6.00	3.00	5.00	5.00	3.00	3.00	4.00
6.00	5.00	5.00	5.00	4.00	86.00	5.00	5.00	4.00	5.00	5.00	5.00	4.00	5.00	3.00	4.00	3.00	6.00
1.00	2.00	4.00	4.00	6.00	68.00	1.00	2.00	4.00	4.00	4.00	6.00	3.00	4.00	3.00	5.00	4.00	4.00
4.00	7.00	4.00	3.00	7.00	103.00	2.00	4.00	4.00	6.00	6.00	7.00	4.00	6.00	7.00	2.00	6.00	4.00
1.00	2.00	2.00	1.00	2.00	50.00	4.00	5.00	6.00	6.00	5.00	3.00	2.00	5.00	5.00	3.00	4.00	5.00
4.00	4.00	2.00	1.00	2.00	69.00	6.00	6.00	5.00	6.00	6.00	6.00	6.00	6.00	3.00	5.00	2.00	5.00
3.00	2.00	2.00	2.00	4.00	45.00	4.00	4.00	5.00	5.00	5.00	5.00	4.00	4.00	1.00	3.00	4.00	5.00
7.00	6.00	7.00	4.00	6.00	95.00	5.00	6.00	4.00	6.00	7.00	5.00	4.00	6.00	5.00	3.00	4.00	4.00
1.00	2.00	2.00	2.00	4.00	47.00	1.00	1.00	2.00	2.00	1.00	3.00	2.00	2.00	1.00	7.00	1.00	3.00
5.00	5.00	3.00	2.00	6.00	72.00	6.00	6.00	6.00	7.00	6.00	7.00	5.00	5.00	5.00	3.00	5.00	3.00
3.00	3.00	2.00	1.00	3.00	56.00	3.00	6.00	5.00	4.00	7.00	5.00	3.00	6.00	4.00	4.00	3.00	4.00
5.00	6.00	2.00	2.00	5.00	82.00	3.00	4.00	4.00	5.00	4.00	5.00	5.00	5.00	1.00	2.00	6.00	5.00
1.00	4.00	1.00	1.00	4.00	60.00	4.00	7.00	5.00	7.00	7.00	7.00	5.00	6.00	6.00	6.00	6.00	4.00
6.00	5.00	3.00	2.00	3.00	75.00	4.00	5.00	5.00	6.00	7.00	5.00	2.00	4.00	5.00	3.00	3.00	3.00
2.00	4.00	4.00	3.00	4.00	71.00	4.00	5.00	4.00	6.00	3.00	6.00	3.00	6.00	4.00	3.00	3.00	3.00
3.00	6.00	6.00	4.00	4.00	78.00	4.00	4.00	4.00	6.00	7.00	7.00	5.00	5.00	5.00	4.00	5.00	5.00
1.00	4.00	1.00	1.00	1.00	39.00	4.00	4.00	4.00	4.00	1.00	4.00	4.00	5.00	7.00	1.00	4.00	4.00

VisSur	Slate2	Slate4	IdeSoun	LocSoun	SensMov	ExmObj	ExObjVi	Slate1	Involve	Delay (+)	Delay	AdjExp	Profici	DispQua (+)	DispQual
2.00	1.00	2.00	1.00	1.00	3.00	4.00	3.00	3.00	4.00	2.00	6.00	3.00	3.00	2.00	6.00
6.00	1.00	1.00	1.00	1.00	2.00	3.00	4.00	1.00	1.00	4.00	4.00	3.00	3.00	2.00	6.00
5.00	4.00	4.00	1.00	1.00	5.00	4.00	4.00	4.00	4.00	1.00	7.00	7.00	5.00	1.00	7.00
2.00	1.00	2.00	1.00	1.00	3.00	2.00	3.00	3.00	2.00	2.00	6.00	5.00	3.00	2.00	6.00
6.00	5.00	6.00	1.00	1.00	5.00	7.00	6.00	6.00	6.00	1.00	7.00	7.00	5.00	2.00	6.00
5.00	2.00	3.00	1.00	1.00	4.00	5.00	6.00	4.00	4.00	4.00	4.00	4.00	4.00	1.00	7.00
7.00	6.00	6.00	1.00	1.00	6.00	6.00	7.00	5.00	6.00	4.00	4.00	5.00	3.00	1.00	7.00
4.00	4.00	3.00	1.00	1.00	3.00	4.00	4.00	4.00	3.00	4.00	4.00	3.00	3.00	3.00	5.00
5.00	1.00	2.00	1.00	1.00	3.00	4.00	4.00	3.00	4.00	2.00	6.00	4.00	3.00	4.00	4.00
6.00	4.00	5.00	1.00	1.00	5.00	3.00	4.00	3.00	5.00	2.00	6.00	7.00	5.00	2.00	6.00
5.00	7.00	7.00	1.00	1.00	7.00	3.00	1.00	6.00	7.00	1.00	7.00	5.00	2.00	1.00	7.00
4.00	4.00	5.00	2.00	2.00	5.00	4.00	5.00	6.00	6.00	3.00	5.00	5.00	2.00	3.00	5.00
5.00	5.00	5.00	1.00	1.00	4.00	5.00	5.00	5.00	5.00	1.00	7.00	7.00	7.00	1.00	7.00
5.00	2.00	2.00	1.00	1.00	3.00	7.00	6.00	2.00	4.00	2.00	6.00	4.00	2.00	1.00	7.00
4.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00	3.00	5.00	3.00	2.00	1.00	4.00	4.00
5.00	4.00	5.00	4.00	4.00	5.00	7.00	7.00	6.00	6.00	2.00	6.00	6.00	4.00	2.00	6.00
4.00	2.00	3.00	1.00	1.00	4.00	2.00	3.00	3.00	5.00	1.00	7.00	4.00	1.00	2.00	6.00
2.00	3.00	4.00	1.00	1.00	4.00	4.00	3.00	5.00	4.00	2.00	6.00	4.00	3.00	3.00	5.00
4.00	2.00	2.00	1.00	1.00	2.00	2.00	2.00	3.00	3.00	3.00	5.00	3.00	2.00	1.00	7.00
4.00	1.00	3.00	5.00	4.00	4.00	2.00	2.00	4.00	4.00	3.00	5.00	4.00	2.00	2.00	6.00
4.00	5.00	5.00	7.00	7.00	6.00	4.00	4.00	6.00	6.00	3.00	5.00	4.00	4.00	4.00	4.00
3.00	3.00	5.00	5.00	2.00	6.00	4.00	1.00	5.00	6.00	2.00	6.00	4.00	3.00	1.00	7.00
3.00	5.00	5.00	6.00	4.00	5.00	4.00	4.00	5.00	5.00	2.00	6.00	4.00	5.00	3.00	5.00
3.00	2.00	4.00	3.00	2.00	6.00	4.00	5.00	5.00	4.00	2.00	6.00	3.00	2.00	3.00	5.00
3.00	3.00	3.00	6.00	4.00	3.00	3.00	3.00	4.00	4.00	2.00	6.00	5.00	4.00	2.00	6.00
5.00	5.00	3.00	5.00	4.00	5.00	3.00	4.00	5.00	6.00	3.00	5.00	3.00	4.00	3.00	5.00
4.00	1.00	1.00	4.00	1.00	4.00	2.00	3.00	4.00	6.00	4.00	4.00	3.00	1.00	4.00	4.00
4.00	4.00	5.00	6.00	6.00	6.00	5.00	5.00	6.00	6.00	2.00	6.00	4.00	5.00	4.00	4.00
5.00	6.00	5.00	6.00	5.00	5.00	4.00	4.00	6.00	6.00	2.00	6.00	6.00	3.00	4.00	4.00
5.00	5.00	6.00	7.00	7.00	7.00	6.00	6.00	6.00	6.00	3.00	5.00	7.00	5.00	1.00	7.00
5.00	4.00	4.00	4.00	3.00	5.00	4.00	4.00	5.00	5.00	2.00	6.00	6.00	5.00	3.00	5.00
5.00	3.00	3.00	6.00	5.00	4.00	5.00	5.00	4.00	4.00	2.00	6.00	4.00	3.00	2.00	6.00
6.00	4.00	5.00	5.00	3.00	5.00	6.00	6.00	6.00	6.00	2.00	6.00	4.00	4.00	2.00	6.00
5.00	3.00	3.00	7.00	5.00	4.00	5.00	5.00	4.00	5.00	4.00	4.00	5.00	5.00	6.00	2.00
4.00	1.00	1.00	6.00	5.00	4.00	4.00	2.00	5.00	5.00	2.00	6.00	3.00	2.00	1.00	7.00
4.00	5.00	6.00	6.00	5.00	5.00	5.00	5.00	5.00	5.00	3.00	5.00	5.00	4.00	2.00	6.00
6.00	5.00	5.00	6.00	6.00	5.00	6.00	5.00	5.00	6.00	3.00	5.00	7.00	6.00	2.00	6.00
4.00	5.00	7.00	7.00	6.00	6.00	5.00	4.00	6.00	7.00	2.00	6.00	5.00	5.00	2.00	6.00
5.00	3.00	3.00	6.00	6.00	4.00	4.00	5.00	6.00	6.00	2.00	6.00	4.00	3.00	1.00	7.00
4.00	2.00	2.00	4.00	5.00	5.00	5.00	6.00	4.00	4.00	3.00	5.00	4.00	3.00	5.00	3.00
4.00	3.00	5.00	5.00	5.00	4.00	3.00	4.00	4.00	5.00	4.00	4.00	5.00	4.00	5.00	3.00
5.00	4.00	6.00	7.00	6.00	4.00	4.00	6.00	6.00	6.00	2.00	6.00	7.00	6.00	4.00	4.00
5.00	5.00	5.00	4.00	3.00	4.00	4.00	4.00	5.00	5.00	1.00	7.00	7.00	6.00	1.00	7.00
5.00	5.00	5.00	6.00	5.00	5.00	5.00	5.00	5.00	6.00	1.00	7.00	6.00	4.00	4.00	4.00
4.00	5.00	5.00	6.00	5.00	5.00	3.00	5.00	5.00	5.00	3.00	5.00	5.00	5.00	2.00	6.00
6.00	4.00	5.00	6.00	5.00	5.00	7.00	4.00	5.00	6.00	1.00	7.00	7.00	7.00	1.00	7.00
6.00	6.00	4.00	7.00	6.00	6.00	6.00	6.00	5.00	7.00	3.00	5.00	6.00	6.00	3.00	5.00
7.00	4.00	3.00	6.00	5.00	6.00	5.00	4.00	5.00	6.00	2.00	6.00	3.00	3.00	1.00	7.00
3.00	5.00	6.00	5.00	3.00	5.00	4.00	2.00	5.00	7.00	3.00	5.00	5.00	4.00	1.00	7.00
6.00	6.00	7.00	7.00	7.00	5.00	4.00	5.00	6.00	7.00	6.00	2.00	7.00	6.00	4.00	4.00
6.00	4.00	6.00	6.00	5.00	5.00	4.00	5.00	6.00	5.00	1.00	7.00	6.00	6.00	3.00	5.00
5.00	4.00	5.00	6.00	4.00	3.00	3.00	4.00	4.00	6.00	6.00	2.00	6.00	2.00	2.00	6.00
4.00	4.00	5.00	6.00	4.00	3.00	3.00	2.00	4.00	5.00	5.00	3.00	4.00	5.00	2.00	6.00
5.00	4.00	1.00	7.00	7.00	2.00	4.00	4.00	2.00	2.00	1.00	7.00	4.00	3.00	2.00	6.00
4.00	1.00	5.00	7.00	4.00	4.00	4.00	4.00	5.00	4.00	4.00	4.00	4.00	1.00	2.00	6.00
4.00	4.00	6.00	5.00	6.00	7.00	5.00	5.00	6.00	6.00	2.00	6.00	5.00	3.00	2.00	6.00
5.00	4.00	5.00	6.00	6.00	4.00	4.00	3.00	5.00	5.00	5.00	3.00	3.00	2.00	2.00	6.00
6.00	3.00	3.00	6.00	5.00	5.00	5.00	5.00	4.00	5.00	2.00	6.00	5.00	3.00	2.00	6.00
3.00	3.00	4.00	5.00	3.00	5.00	3.00	3.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
3.00	4.00	5.00	5.00	4.00	4.00	3.00	5.00	5.00	4.00	3.00	5.00	4.00	3.00	3.00	5.00
6.00	6.00	6.00	6.00	5.00	7.00	6.00	6.00	6.00	7.00	1.00	7.00	7.00	6.00	1.00	7.00
5.00	1.00	1.00	5.00	5.00	4.00	3.00	2.00	3.00	4.00	2.00	6.00	5.00	3.00	3.00	5.00
6.00	1.00	3.00	5.00	5.00	4.00	4.00	5.00	5.00	5.00	4.00	4.00	5.00	4.00	2.00	6.00
4.00	3.00	5.00	6.00	6.00	4.00	4.00	3.00	5.00	5.00	3.00	5.00	3.00	5.00	1.00	7.00
6.00	3.00	3.00	6.00	4.00	5.00	4.00	5.00	4.00	5.00	2.00	6.00	7.00	6.00	3.00	5.00
4.00	4.00	2.00	4.00	3.00	4.00	3.00	4.00	2.00	4.00	4.00	4.00	4.00	2.00	4.00	4.00
5.00	5.00	6.00	6.00	5.00	6.00	4.00	3.00	5.00	7.00	4.00	4.00	3.00	1.00	2.00	6.00
6.00	2.00	2.00	6.00	6.00	4.00	5.00	6.00	3.00	5.00	4.00	4.00	4.00	2.00	1.00	7.00
5.00	1.00	3.00	6.00	6.00	5.00	4.00	4.00	5.00	5.00	2.00	6.00	6.00	4.00	3.00	5.00
6.00	2.00	3.00	6.00	5.00	5.00	4.00	3.00	5.00	5.00	2.00	6.00	5.00	4.00	2.00	6.00
6.00	5.00	6.00	5.00	5.00	5.00	6.00	5.00	5.00	6.00	1.00	7.00	7.00	4.00	2.00	6.00
2.00	1.00	1.00	2.00	1.00	1.00	3.00	1.00	1.00	2.00	2.00	6.00	1.00	1.00	7.00	1.00
5.00	5.00	5.00	6.00	5.00	5.00	5.00	5.00	5.00	6.00	2.00	6.00	6.00	6.00	2.00	6.00
3.00	3.00	3.00	6.00	6.00	3.00	2.00	2.00	5.00	4.00	1.00	7.00	4.00	3.00	2.00	6.00
4.00	5.00	5.00	6.00	5.00	6.00	5.00	5.00	5.00	5.00	3.00	5.00	4.00	3.00	4.00	4.00
6.00	6.00	6.00	5.00	1.00	7.00	7.00	4.00	6.00	7.00	2.00	6.00	4.00	4.00	2.00	6.00
4.00	4.00	3.00	6.00	2.00	4.00	5.00	2.00	5.00	4.00	2.00	6.00	5.00	4.00	1.00	7.00
4.00	2.00	5.00	6.00	4.00	3.00	2.00	2.00	4.00	4.00	3.00	5.00	3.00	3.00	1.00	7.00
4.00	2.00	5.00	7.00	4.00	5.00	4.00	6.00	5.00	7.00	5.00	3.00	5.00	4.00	5.00	3.00
4.00	4.00	5.00	5.00	4.00	4.00	2.00	3.00	5.00	6.00	3.00	5.00	4.00	4.00	2.00	6.00

ContDev (+)	ContDev	Concen	Comfoc	Inform	PQ.Tot	Slater.Tot	Adj.PQ.Tot	PQ.Tot.w.o.Sound	Adj.PQ.Tot.w.o.Sound	ITQ.avg	PQ.avg
4.00	4.00	2.00	3.00	5.00	74.00	1.00	50.00	71.00	50.00	74.15	96.85
5.00	3.00	2.00	2.00	1.00	69.00	0.00	45.00	66.00	45.00		
4.00	4.00	4.00	6.00	6.00	109.00	0.00	85.00	106.00	85.00		
5.00	3.00	4.00	4.00	3.00	80.00	0.00	56.00	77.00	56.00		
4.00	4.00	6.00	4.00	1.00	122.00	0.00	98.00	119.00	98.00		
3.00	5.00	4.00	5.00	4.00	104.00	0.00	80.00	101.00	80.00		
4.00	4.00	4.00	5.00	2.00	111.00	3.00	87.00	105.00	84.00		
3.00	5.00	4.00	3.00	1.00	73.00	0.00	49.00	70.00	49.00		
4.00	4.00	4.00	3.00	1.00	81.00	0.00	57.00	78.00	57.00		
3.00	5.00	5.00	4.00	1.00	106.00	1.00	82.00	103.00	82.00		
5.00	3.00	4.00	5.00	6.00	108.00	5.00	84.00	100.00	79.00		
4.00	4.00	3.00	6.00	6.00	105.00	3.00	81.00	98.00	77.00		
3.00	5.00	7.00	7.00	5.00	122.00	1.00	98.00	119.00	98.00		
1.00	7.00	2.00	4.00	2.00	92.00	0.00	68.00	89.00	68.00		
4.00	4.00	1.00	2.00	2.00	58.00	0.00	34.00	55.00	34.00		
3.00	5.00	6.00	6.00	6.00	124.00	2.00	100.00	111.00	90.00		
3.00	5.00	2.00	6.00	1.00	83.00	0.00	59.00	80.00	59.00		
3.00	5.00	4.00	5.00	4.00	86.00	0.00	62.00	83.00	62.00		
4.00	4.00	3.00	4.00	1.00	76.00	0.00	52.00	73.00	52.00		
6.00	2.00	2.00	3.00	5.00	89.00	1.00	65.00	75.00	54.00		
5.00	3.00	5.00	6.00	6.00	123.00	2.00	99.00	102.00	81.00	76.85	112.20
5.00	3.00	4.00	5.00	5.00	104.00	1.00	80.00	91.00	70.00		
5.00	3.00	4.00	6.00	5.00	109.00	1.00	85.00	94.00	73.00		
6.00	2.00	3.00	4.00	5.00	91.00	1.00	67.00	83.00	62.00		
6.00	2.00	2.00	3.00	3.00	92.00	0.00	68.00	78.00	57.00		
4.00	4.00	3.00	5.00	5.00	108.00	2.00	84.00	94.00	73.00		
7.00	1.00	4.00	4.00	4.00	78.00	1.00	54.00	68.00	47.00		
5.00	3.00	3.00	4.00	5.00	118.00	2.00	94.00	99.00	78.00		
1.00	7.00	6.00	7.00	6.00	123.00	4.00	99.00	106.00	85.00		
3.00	5.00	6.00	7.00	6.00	141.00	3.00	117.00	120.00	99.00		
2.00	6.00	6.00	5.00	5.00	123.00	0.00	99.00	110.00	89.00		
4.00	4.00	6.00	4.00	5.00	107.00	0.00	83.00	91.00	70.00		
5.00	3.00	3.00	4.00	5.00	112.00	2.00	88.00	99.00	78.00		
5.00	3.00	4.00	5.00	5.00	112.00	0.00	88.00	94.00	73.00		
4.00	4.00	4.00	4.00	6.00	100.00	0.00	76.00	84.00	63.00		
6.00	2.00	3.00	6.00	6.00	114.00	1.00	90.00	98.00	77.00		
2.00	6.00	3.00	6.00	6.00	139.00	0.00	115.00	120.00	99.00		
3.00	5.00	2.00	6.00	5.00	126.00	3.00	102.00	106.00	85.00		
4.00	4.00	4.00	5.00	7.00	117.00	0.00	93.00	99.00	78.00		
6.00	2.00	4.00	5.00	5.00	107.00	1.00	83.00	92.00	71.00		
3.00	5.00	4.00	5.00	5.00	104.00	0.00	80.00	89.00	68.00	76.25	110.90
2.00	6.00	6.00	6.00	7.00	132.00	3.00	108.00	114.00	93.00		
4.00	4.00	4.00	6.00	7.00	114.00	5.00	90.00	101.00	80.00		
4.00	4.00	5.00	5.00	6.00	129.00	1.00	105.00	112.00	91.00		
3.00	5.00	6.00	5.00	5.00	115.00	1.00	91.00	99.00	78.00		
1.00	7.00	6.00	7.00	7.00	146.00	0.00	122.00	128.00	107.00		
6.00	2.00	4.00	6.00	6.00	125.00	1.00	101.00	107.00	86.00		
3.00	5.00	6.00	4.00	6.00	121.00	0.00	97.00	104.00	83.00		
4.00	4.00	4.00	5.00	4.00	108.00	1.00	84.00	93.00	72.00		
5.00	3.00	6.00	7.00	7.00	133.00	6.00	109.00	112.00	91.00		
1.00	7.00	7.00	6.00	7.00	126.00	4.00	102.00	109.00	88.00		
6.00	2.00	4.00	4.00	6.00	104.00	1.00	80.00	88.00	67.00		
3.00	5.00	6.00	6.00	5.00	103.00	0.00	79.00	87.00	66.00		
4.00	4.00	4.00	3.00	6.00	108.00	0.00	84.00	88.00	67.00		
1.00	7.00	2.00	4.00	5.00	104.00	0.00	80.00	88.00	67.00		
6.00	2.00	4.00	5.00	6.00	111.00	3.00	87.00	94.00	73.00		
6.00	2.00	2.00	4.00	6.00	99.00	0.00	75.00	81.00	60.00		
3.00	5.00	5.00	4.00	6.00	122.00	0.00	98.00	105.00	84.00		
6.00	2.00	2.00	3.00	3.00	88.00	0.00	64.00	76.00	55.00		
5.00	3.00	5.00	3.00	4.00	91.00	0.00	67.00	79.00	58.00		
5.00	3.00	4.00	6.00	7.00	141.00	5.00	117.00	124.00	103.00	68.40	109.95
5.00	3.00	3.00	2.00	5.00	99.00	1.00	75.00	83.00	62.00		
7.00	1.00	3.00	3.00	6.00	103.00	0.00	79.00	87.00	66.00		
1.00	7.00	6.00	4.00	4.00	111.00	0.00	87.00	93.00	72.00		
3.00	5.00	5.00	5.00	5.00	122.00	0.00	98.00	107.00	86.00		
4.00	4.00	4.00	4.00	4.00	89.00	0.00	65.00	76.00	55.00		
4.00	4.00	2.00	4.00	7.00	106.00	4.00	82.00	88.00	67.00		
5.00	3.00	5.00	4.00	7.00	113.00	0.00	89.00	98.00	77.00		
3.00	5.00	6.00	4.00	7.00	129.00	1.00	105.00	111.00	90.00		
3.00	5.00	5.00	4.00	5.00	113.00	0.00	89.00	97.00	76.00		
4.00	4.00	4.00	3.00	4.00	120.00	2.00	96.00	105.00	84.00		
4.00	4.00	1.00	1.00	1.00	51.00	0.00	27.00	45.00	24.00		
4.00	4.00	6.00	6.00	6.00	131.00	1.00	107.00	113.00	92.00		
5.00	3.00	3.00	3.00	5.00	100.00	1.00	76.00	83.00	62.00		
3.00	5.00	5.00	6.00	6.00	112.00	1.00	88.00	96.00	75.00		
7.00	1.00	6.00	7.00	7.00	129.00	6.00	105.00	116.00	95.00		
4.00	4.00	4.00	4.00	5.00	103.00	1.00	79.00	90.00	69.00		
2.00	6.00	5.00	6.00	6.00	106.00	0.00	82.00	90.00	69.00		
3.00	5.00	7.00	7.00	4.00	119.00	1.00	95.00	101.00	80.00		
4.00	4.00	5.00	6.00	6.00	102.00	1.00	78.00	89.00	68.00		

PQ.w.o.Sound.avg	Adj.PQ.avg	Adj.PQ.w.o.Sound.avg	VisTotal	AvgPQScore	AvgSlaterScore
90.95	72.85	69.95	16.00	2.96	3.00
			25.00	2.75	1.33
			21.00	4.42	4.17
			20.00	3.21	2.00
			30.00	4.96	5.83
			19.00	4.21	3.17
			19.00	4.38	5.17
			21.00	2.92	3.50
			22.00	3.25	2.17
			26.00	4.29	4.17
			27.00	4.17	6.00
			28.00	4.08	5.33
			25.00	4.96	5.00
			24.00	3.71	2.67
			23.00	2.29	1.33
			26.00	4.63	5.00
			16.00	3.33	3.17
			19.00	3.46	3.50
			29.00	3.04	2.67
			21.00	3.13	3.17
96.40	88.20	75.40	20.00	4.25	4.83
			15.00	3.79	4.67
			22.00	3.92	4.67
			25.00	3.46	3.83
			12.00	3.25	3.17
			17.00	3.92	5.00
			19.00	2.83	3.50
			23.00	4.13	4.50
			18.00	4.42	5.67
			17.00	5.00	5.50
			12.00	4.58	3.83
			22.00	3.79	3.50
			30.00	4.13	5.00
			26.00	3.92	3.33
			29.00	3.50	2.67
			24.00	4.08	5.00
			26.00	5.00	5.00
			27.00	4.42	5.67
			24.00	4.13	4.00
			20.00	3.83	3.50
95.70	86.90	74.70	21.00	3.71	3.67
			21.00	4.75	4.67
			22.00	4.21	4.83
			21.00	4.67	5.17
			22.00	4.13	5.00
			29.00	5.33	4.17
			13.00	4.46	4.50
			12.00	4.33	3.83
			25.00	3.88	5.00
			22.00	4.67	6.17
			21.00	4.54	5.00
			20.00	3.67	4.33
			17.00	3.63	3.83
			23.00	3.67	1.83
			23.00	3.67	3.00
			18.00	3.92	5.33
			24.00	3.38	4.33
			26.00	4.38	4.00
			14.00	3.17	4.00
			18.00	3.29	4.17
94.60	85.95	73.60	27.00	5.17	5.33
			17.00	3.46	2.83
			22.00	3.63	2.83
			24.00	3.88	4.33
			24.00	4.46	3.50
			26.00	3.17	3.17
			18.00	3.67	5.83
			25.00	4.08	3.50
			16.00	4.63	3.33
			25.00	4.04	3.33
			25.00	4.38	5.33
			15.00	1.88	1.00
			22.00	4.71	5.17
			22.00	3.46	4.17
			29.00	4.00	4.33
			26.00	4.83	6.17
			24.00	3.75	4.50
			31.00	3.75	3.50
			20.00	4.21	4.83
			21.00	3.71	4.33

APPENDIX B. EXPERIMENT PROTOCOL

I. Consent forms

A. Have participant read and sign consent forms.
B. Assign participant a subject ID and Condition.
C. Condition values:
   1. 1 – No sound
   2. 2 – Speakers
   3. 3 – Headphones without subwoofer
   4. 4 – Headphones with subwoofer

II. Initialize ITQ on computer 1

A. Logon to computer.
B. Start MediaLab by double-clicking on the desktop icon.
C. Click on Run in the menu bar.
   1. click on Select and run an experiment.
   2. select c:\Documents and Settings\Administrator\Desktop\QUESTIONNAIRES
   3. select AudioEffectOnPresence
   4. click on Open
   5. Go to step III.

III. Immersive Tendencies Questionnaire

A. Input subject ID and condition as assigned in step I above.
B. Have participant complete ITQ on computer 1.
   1. Have participant answer questions.
   2. If participant should come to you about any health concerns, determine if concern precludes participant from participating in the experiment. If NO, have participant continue with questionnaire by pressing 1. If YES, press 2 on computer and thank the participant for volunteering.
C. When participant finishes the ITQ, move him to computer 2 for practice (step IV).

IV. Medal of Honor Practice

A. Logon to computer in the Multimedia Lab.
   1. Start MOHAA by doubleclicking on the MOHAA shortcut on the desktop (ensure MOHAA disc 1 is in the drive)
   2. Press any button to exit the introduction

B. Click on the wall map
   1. Click on the Basic Training clipboard.
   2. Have the participant follow the DI’s instructions.

C. Once the participant is finished with the tutorial, go to step VI.

V. Biograph setup

A. Logon to computer in side room.
B. Double click on the BioGraph 2.1 icon.
C. Click on OK
D. Click on Load a Display Screen.
E. Under Categories, select Pilot Study (if not selected) and then select Pilot Study under Display Screens. Click on Load.
F. Click on Start New.
   1. Highlight Thesis, Audio
   2. Ensure battery is at least 30%. If not, replace batteries
G. Click on Start.
H. Once the session is over, click Stop (button with a black square on it).
I. Click YES on the Do you want to save the recording for client Thesis, Audio?
   1. Enter sub#cond* for the description (where # is the participant’s ID number and * is the condition number).
   2. Press OK.
   3. Copy the session to our PhysData file
      a. Click on File in the menu bar
      b. Select Load Session from the drop down menu.
      c. Highlight the session you want to copy.
      d. Click on the Copy Session to: button.
      e. Type in C:\PhysData in the Enter destination for client data: dialog box
      f. Click OK
J. Ensure sensor cables on in the right port on the ProComp+.
   1. Port A: EKG
   2. Port E: GSR
   3. Port F: Temperature
   4. Port G: BVP

VI. Attach sensors to participant

A. All sensors (except EKG) go on the participants left hand.

1. Temperature sensor attaches to the participant’s left pinky finger using the Velcro. The sensor should be on the pad of the finger.
2. GSR sensors go on the participant’s middle finger.
    a. One sensor is wrapped around the base of the finger.
    b. One sensor is wrapped around the next joint up from the base.
3. BVP sensor goes on the participant’s thumb with the decal pointing away from the thumb. Use the two black elastic loops to secure the sensor on the thumb.

B. EKG cables attach to both forearms.

1. The blue connector goes on a pad attached to the inside of the participant’s left wrist.
2. The black connector goes on a pad attached to the participant’s forearm just below the left elbow joint.
3. The yellow connector goes on a pad attached to the inside of the participant’s right wrist.

VII. MOHAA Experiment setup

A. Logon to computer.

B. Set the audio volume for the condition to be tested

1. Go to Start/Settings/Control Panel and click on the AudioHQ icon.
2. Click on the Mixer icon.
    a. For the No Sound condition (condition 1) check the mute box under the volume slider.
    b. For the Speakers condition (condition 2), ensure the following settings on the mixer panel:
        1. **Volume: 45%**
        2. **Bass: 75%**
        3. All other sliders: 50% (the last two sliders in the panel should be muted).
        4. Click on the Advanced mode button at the bottom left of the mixer window (if it is

already in advanced mode, the button will be labeled Basic mode).

a. Set speakers to 5.1 speakers

c. For the Headphone without subwoofer condition (condition 3), ensure the following settings on the mixer panel:

1. **Volume: 100%**
2. **Bass: 22%**
3. All other sliders: 50% (the last two sliders in the panel should be muted).
4. Click on the Advanced mode button at the bottom left of the mixer window (if it is already in advanced mode, the button will be labeled Basic mode).
   a. Set speakers to Headphones
   b. Turn off all the Genelec speakers including the subwoofer.

d. For the Headphones with subwoofer condition (condition 4), ensure the following settings on the mixer panel:

1. **Volume: 100%**
2. **Bass: 22%**
3. All other sliders: 50% (the last two sliders in the panel should be muted).
4. Click on the Advanced mode button at the bottom left of the mixer window (if it is already in advanced mode, the button will be labeled Basic mode).
   a. Set speakers to Headphones
   b. Turn off all the Genelec speakers except the subwoofer.

C. Click on the in/out box on the desk

1. Click on the Load/Save trays.
2. Highlight “Omaha Beach – The Landing” with the elapsed time of **0:05:52**.
3. Click on Load.

D. Inform the participant not to press “Continue” until told to do so.

E. Start the video camera
   1. Turn power button to Cam Corder
   2. Ensure tape is loaded
   3. Ensure view has both computer monitor and participant
   4. Start the camera just prior to the participant starting the game.
F. When the participant is finished, direct him/her back to the first computer to answer the PQ.

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APPENDIX C. INBRIEF SCRIPT

GENERAL:

The following intel brief was provided to each participant prior to participation in this experiment. The intel brief appears in the same format used for the experiment and does not follow the standard thesis format utilized in this thesis.

INTEL BRIEF
Normandy Invasion
Omaha Beach, Charlie Sector

You are 2nd Lt. Mike Powell, 2nd Ranger Battalion, an integral part of the Omaha Beach invasion of June 1944. You have made it past the open beach alive and are at the “shingle”. You are required to retrieve bangalores and bring them back to the shingle to clear the wire. The bangalores are off to your left and a little towards the water. You will have to expose yourself to enemy fire in order to retrieve the bangalores, but your battalion can’t proceed without them.

Once the wire is cleared, make your way to the base of the bunker. Once at the bunker, Capt. Schmuck will send two brave souls out to reach the trench at the base of the second bunker. If they do not make it, you will have to do it. Between the bunkers and the trench is a minefield – choose your path carefully, but quickly. On the hill between the bunkers are a couple of machine gun nests that are waiting for you to get out in the open.

Once you make it to the trench, you must infiltrate the bunker, take it over, and take out the machine gun nests and second bunker. Make your way through the bunker carefully. You never know when you will run into a Nazi.

APPENDIX D. CONSENT FORMS

GENERAL:

The forms in the appendix appear in the same format used for the experiment and do not follow the standard thesis format utilized in this thesis. This appendix consists of three documents: Consent Form, Minimal Risk Consent Statement, and the Privacy Act Statement. Each subject is required to read and sign these documents prior to participating in the experiment.

PARTICIPANT CONSENT FORM

1. **Introduction.** You are invited to participate in a study exploring how sound affects the human physiology. This research is aimed at improving sound systems in virtual environments. You will be playing a scenario in Medal of Honor: Allied Assault. After the scenario you will complete a presence questionnaire to indicate how present you felt in the environment. Your recorded data will be used in a effort to determine if a person's sense of presence is correlated with the body's physiological responses.

2. **Background Information.** Data is being collected by the Naval Postgraduate School's Human System's Integration Laboratory for use in developing virtual environments.

3. **Procedures.** If you agree to participate in this study, the researcher will explain the tasks in detail. Auditory stimuli will be presented over different speaker configurations while visual stimuli are presented over the same delivery means. You will be connected to a computer via a junction box and several wires that will be harmlessly attached your body. You will use the mouse and keyboard to play a Medal of Honor game scenario. The intent is for you to play the game to the best of your ability. The entire task will take approximately 30 minutes.

4. **Risks and Benefits.** Because this research involves minimal risks to individuals with cardiac risk factors, we request that IF YOU CONSIDER YOURSELF AS SUCH, PLEASE INFORM THE EXPERIIMENT ADMINISTRATOR AT ONCE, and NOT PROCEED ANY FURTHER. The benefits to the participants will be to contribute to current research in advancing presence in virtual environments and in human-computer interaction.

5. **Compensation.** No tangible reward will be given. A copy of the results will be available to you at the conclusion of the experiment.

6. **Confidentiality.** The records of this study will be kept confidential. No information will be publicly accessible which could identify you as a participant.

7. **Voluntary Nature of the Study.** If you agree to participate, you are free to withdraw from the study at any time without prejudice. You will be provided a copy of this form for your records.

8. **Points of Contact.** If you have any further questions or comments after the completion of the study, you may contact the research supervisor, Dr. Russell Shilling (831) 656-2543 shilling@cs.nps.navy.mil.

9. **Statement of Consent.** I have read the above information. I have asked all questions and have had my questions answered. I agree to participate in this study.

-- ---------------------------

Participant's Signature Date

-- ---------------------------

Researcher's Signature Date

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943
MINIMAL RISK CONSENT STATEMENT

Participant:

VOLUNTARY CONSENT TO BE A RESEARCH PARTICIPANT IN: SOUND SYSTEM COMPLEXITY AND ITS EFFECT ON THE USER'S SENSE OF PRESENCE IN A VIRTUAL ENVIRONMENT.

1. I have read, understand and been provided "Information for Participants" that provides the details of the below acknowledgments.

2. I understand that this project involves research. An explanation of the purposes of the research, a description of procedures to be used, identification of experimental procedures, and the extended duration of my participation have been provided to me.

3. I understand that this project does not involve more than minimal risk. I have been informed of any reasonably foreseeable risks or discomforts to me.

4. I have been informed of any benefits to me or to others that may reasonably be expected from the research.

5. I have signed a statement describing the extent to which confidentiality of records identifying me will be maintained.

6. I have been informed of any compensation and/or medical treatments available if injury occurs and if so, what they consist of, or where further information may be obtained.

7. I understand that my participation in this project is voluntary, refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled. I also understand that I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled.

8. I understand that the individual to contact should I need answers to pertinent questions about the research is Professor Russell Shilling, Principal Investigator, and about my rights as a research participant or concerning a research related injury is the Modeling Virtual Environments and Simulation Chairman. A full and responsive discussion of the elements of this project and my consent has taken place.

Medical Monitor: Flight Surgeon, Naval Postgraduate School

_______________________________________ _______________________________________
Signature of Principal Investigator Date Signature of Volunteer Date

____
Signature of Witness Date

PRIVACY ACT STATMENT

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943
PRIVACY ACT STATEMENT

1. Authority: Naval Instruction

2. Purpose: DETERMINE SOUND SYSTEM COMPLEXITY AND ITS EFFECT ON THE USER'S SENSE OF PRESENCE IN A VIRTUAL ENVIRONMENT

3. Use: Physiological response data will be used for statistical analysis by the Departments of the Navy and Defense, and other U.S. Government agencies, provided this use is compatible with the purpose for which the information was collected. The Naval Postgraduate School in accordance with the provisions of the Freedom of Information Act may grant use of the information to legitimate non-government agencies or individuals.

4. Disclosure/Confidentiality:

   a. I have been assured that my privacy will be safeguarded. I will be assigned a control or code number, which thereafter will be the only identifying entry on any of the research records. The Principal Investigator will maintain the cross-reference between name and control number. It will be decoded only when beneficial to me or if some circumstances, which are not apparent at this time, would make it clear that decoding would enhance the value of the research data. In all cases, the provisions of the Privacy Act Statement will be honored.

   b. I understand that a record of the information contained in this Consent Statement or derived from the experiment described herein will be retained permanently at the Naval Postgraduate School or by higher authority. I voluntarily agree to its disclosure to agencies or individuals indicated in paragraph 3 and I have been informed that failure to agree to such disclosure may negate the purpose for which the experiment was conducted.

   c. I also understand that disclosure of the requested information is voluntary.

____

Signature of Volunteer   Name, Grade/Rank (if applicable) DOB   Date

____

Signature of Witness   Date

APPENDIX E. QUESTIONNAIRES

GENERAL

The items in this appendix appear in the same format utilized for the experiment and thus do not conform to the standard thesis format utilized in the chapters of this document. This appendix consists of two documents: Immersive Tendencies Questionnaire (ITQ) and a Presence Questionnaire (PQ). The PQ is a combination of two previously used presence questionnaires (Witmer & Singer’s questionnaire and Slater’s questionnaire).

Name	Question Wording / File Name	Answer Choices						
Sleep	How much sleep did you get last night?	<2 hours	2-4 hours	4-6 hours	6-8 hours	>8 hours	none	none
Caffein	How many cups of coffee or caffeinated drinks have you had today?	0	1	2	3	>3	none	none
Gaming	What level of experience do you have with first person shooter games?	No experience	Novice	Average	Experienced	Expert	none	none
Gender	What is your gender?	Male	Female	none	none	none	none	none
Age	What is your age group?	<25	26-30	31-35	36-40	>40	none	none
Hearing	Do you have any significant hearing loss?	Yes	No	none	none	none	none	none
Level	What is your level of hearing loss in dB?	<5 dB	5-10 dB	10-15 dB	>15 dB	none	none	none
Medical	Do you have any health problems that may preclude you from participating in this experiment?	Yes	No	none	none	none	none	none
Concern	Please inform the experimenter of your health concerns.	Continue	End	none	none	none	none	none
Movies	Do you easily become deeply involved in movies or TV dramas?	NEVER	none	none	OCCASIONALLY	none	none	OFTEN
TvBook	Do you ever become so involved in a television program or book that people have problems getting your attention?	NEVER	none	none	OCCASIONALLY	none	none	OFTEN
Alert	How mentally alert do you feel at this time?	NOT ALERT	none	none	MODERATELY	none	none	FULLY ALERT
MovAwar	Do you ever become so involved in a movie that you are not aware of things happening around you?	NEVER	none	none	OCCASIONALLY	none	none	OFTEN
Charact	How frequently do you find yourself closely identifying with the characters in a story line?	NEVER	none	none	OCCASIONALLY	none	none	OFTEN
VidGame	Do you ever become so involved in a video game that it is as if you are inside the game rather than moving a joystick and watching the screen?	NEVER	none	none	OCCASIONALLY	none	none	OFTEN
FitToda	How physically fit do you feel today?	NOT FIT	none	none	MODERATELY	none	none	EXTREMELY FIT
BlockOu	How good are you at blocking out external distractions when you are involved in something?	NOT VERY GOOD	none	none	SOMEWHAT	none	none	VERY GOOD
WatcGam	When watching sports, do you ever bec ome so involved in the game that you react as if you were one of the players?	NEVER	none	none	OCCASIONALLY	none	none	OFTEN
DayDrea	Do you ever become so involved in a daydream that you are not aware of things happening around you?	NEVER	none	none	OCCASIONALLY	none	none	OFTEN
Dreams	Do you ever have dreams that are so real that you feel disoriented when you awake?	NEVER	none	none	OCCASIONALLY	none	none	OFTEN
Sports	When playing sports, do you ever become so involved in the game that you lose track of time?	NEVER	none	none	OCCASIONALLY	none	none	OFTEN

Name	Question Wording / File Name	Answer Choices						
Concent	How well do you concentrate on enjoyable activities?	NOT AT ALL	none	none	MODERATELY	none	none	VERY WELL
PlayVG	How often do you play arcade or video games (Often should be taken to mean every day or every two days, on average)?	NEVER	none	none	OCCASIONALLY	none	none	OFTEN
TvFight	Have you ever gotten excited during a chase or fight scene on TV or in the movies?	NEVER	none	none	OCCASIONALLY	none	none	OFTEN
Scared	Have you ever gotten scared by something happening on TV or in the movies?	NEVER	none	none	OCCASIONALLY	none	none	OFTEN
Fearful	Have you ever remained apprehensive or fearful long after watching a horror movie?	NEVER	none	none	OCCASIONALLY	none	none	OFTEN
LosTack	Do you ever become so involved in doing something that you lose all track of time?	NEVER	none	none	OCCASIONALLY	none	none	OFTEN
End	You are done with the pre-questionnaire. Please inform the experimenter to continue with the next part of the experiment.	none	none	none	none	none	none	none
Control	How much were you able to control events?	NOT AT ALL	none	none	SOMEWHAT	none	none	COMPLETELY
Res-Env	How responsive was the environment to actions that you initiated (or performed)?	NOT AT ALL	none	none	SOMEWHAT	none	none	COMPLETELY
Natural	How natural did your interactions with the environment seem?	NOT AT ALL	none	none	SOMEWHAT	none	none	COMPLETELY
VisAsp	How much did the visual aspects of the environment involve you?	NOT AT ALL	none	none	SOMEWHAT	none	none	COMPLETELY
Slate5	Consider your memory of being in the virtual environment. How similar in terms of the structure of the memory is this to the structure of the memory of other places you have been today?	NOT AT ALL	none	none	SOMEWHAT	none	none	VERY MUCH SO
AudAsp	How much did the auditory aspects of the environment involve you?	NOT AT ALL	none	none	SOMEWHAT	none	none	COMPLETELY
Mechani	How natural was the mechanism that controlled movement through the environment?	NOT AT ALL	none	none	SOMEWHAT	none	none	COMPLETELY
SensObj	How compelling was your sense of objects moving through space?	NOT AT ALL	none	none	SOMEWHAT	none	none	COMPLETELY
Slate3	When you think back on your experience, do you think of the virtual environment more as images that you saw or more as somewhere you visited?	IMAGES I SAW	none	none	none	none	none	SOMEWHERE THAT I VISITED
Consist	How much did your experience in the Virtual Environment seem consistent with your real world experiences?	NOT AT ALL INCONSISTENT	none	none	SOMEWHAT INCONSISTENT	none	none	VERY INCONSISTENT
Slate6	During your experience, did you feel like you were just sitting in the lab using a mouse to interact with a computer, or did the virtual battlefield overwhelm you?	MOST OF THE TIME I REALIZED I WAS IN THE LAB	none	none	SOMETIMES THE BATTLEFIELD OVERWHELMED ME	none	none	I WAS ALWAYS OVERWHELMED BY THE VIRTUAL BATTLEFIELD
Res-Act	Were you able to anticipate what would happen next in response to the actions that you performed?	NOT AT ALL	none	none	SOMEWHAT	none	none	COMPLETELY

Name	Question Wording / File Name	Answer Choices						
VisSur	How completely were you able to actively survey or search the environment using vision?	NOT AT ALL	none	none	SOMEWHAT	none	none	COMPLETELY
Slate2	To what extent were there times during the experience when the virtual battlefield became reality for you and you forgot about the real world of the laboratory?	AT NO TIME	none	none	SOMETIMES	none	none	ALMOST ALL THE TIME
Slate4	During the time of the experience, which was strongest on the whole? Your sense of being on the virtual battlefield or being in the real world of the laboratory.	THE REAL WORLD (THE LAB)	none	none	none	none	none	THE VIRTUAL ENVIRONMENT
IdeSoun	How well could you identify sounds?	NOT AT ALL	none	none	SOMEWHAT	none	none	COMPLETELY
LocSoun	How well could you localize sounds?	NOT AT ALL	none	none	SOMEWHAT	none	none	COMPLETELY
SensMov	How compelling was your sense of moving around inside the virtual battlefield?	NOT COMPELLING	none	none	MODERATELY COMPELLING	none	none	VERY COMPELLING
ExmObj	How closely were you able to examine objects?	NOT AT ALL	none	none	PRETTY CLOSE	none	none	VERY CLOSE
ExObjVi	How well could you examine objects from multiple viewpoints?	NOT AT ALL	none	none	SOMEWHAT	none	none	EXTENSIVELY
Slate1	Rate your sense of being in the Virtual Environment (7 represents your normal experience of being in a place)	NOT AT ALL	none	none	SOMEWHAT	none	none	VERY MUCH
Involve	How involved were you in the virtual environment experience?	NOT INVOLVED	none	none	MILDLY INVOLVED	none	none	VERY INVOLVED
Delay	How much delay did you experience between your actions and expected outcomes?	NO DELAYS	none	none	MODERATE DELAYS	none	none	LONG DELAYS
AdjExp	How quickly did you adjust to the virtual environment experience?	NOT AT ALL	none	none	SLOWLY	none	none	LESS THAN ONE MINUTE
Profici	How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?	NOT PROFICIENT	none	none	REASONABLY PROFICIENT	none	none	VERY PROFICIENT
DispQua	How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?	NOT AT ALL	none	none	SOMEWHAT INTERFERRED	none	none	PREVENTED PERFORMANCE
ContDev	How much did the control devices interfere with the performance of assigned tasks or with other activities?	NOT AT ALL	none	none	SOMEWHAT INTERFERRED	none	none	GREATLY INTERFERRED
Concen	How well could you concentrate on the assigned tasks or required activities rather than on mechanisms used to perform those tasks or activities?	NOT AT ALL	none	none	SOMEWHAT	none	none	COMPLETELY
Comfoc	Were there moments during the virtual environment experience when you felt completely focused on the task or enviroment?	NOT AT ALL	none	none	OCCASIONALLY	none	none	FREQUENTLY
Inform	Was the information provided through the different senses in the virtual environment (e.g. vision, hearing, touch) consistent?	NOT CONSISTENT	none	none	SOMEWHAT CONSISTENT	none	none	VERY CONSISTENT
End2	This completes the experiment. Thank you for your participation.	none	none	none	none	none	none	none

APPENDIX F. EQUIPMENT SPECIFICATIONS

Dell Dimension 8100 (2 used):

CPU	Intel Pentium 4 1.7GHz
RAM	256MB
Hard drive	60GB
Operating System	Windows 2000

Alienware Majestic 12 (1 used):

CPU	Intel Pentium 4 1.8GHz
RAM	512MB
Hard drive	40GB
Operating System	Windows XP

Genelec 1031A Bi-amplified Speaker (Five used):

Free field frequency response of system:	48 Hz - 22 kHz (± 2 dB)
Harmonic distortion at 90 dB SPL @ 1m on axis: Freq: 50...100 Hz > 100 Hz	 < 1% < 0.5%
Drivers: Bass Treble	 210 mm (8") cone 25 mm (1") metal dome
Bass amplifier output power with an 8Ohm load:	120 W
Treble amplifier output power with an 8Ohm load: Long term output power is limited by driver unit protection circuitry.	120 W
Signal to Noise ratio, referred to full output:	Bass > 100 dB Treble > 100 dB

Genelec 1094A Active Subwoofer System (1 used):

Free field frequency response of system (± 2.5 dB):	29 - 80 Hz
Harmonic distortion at 100 dB SPL @ 1m on axis in half space (30...100 Hz):	< 3%
Drivers:	385 mm (15")
Short term amplifier output power:	400 W (8 Ohm)
Signal to Noise ratio, referred to full output:	> 100 dB

Sennheiser Headphones model 570HD (1 pair used):

Frequency Response	18 - 22000 Hz
Weight w/o cable	ca. 210 g
Design	Open

CEL Instruments CEL-231 Digital Sound Survey Meter

Range	Low: 30-100dB High: 65-135dB
Accuracy	± 1dB
Last calibration	THX™ 6/21/00

Thought Technology Physiological Sensors:

ProComp+ Encoder (SA7008P)

Size (approx.)	81mm x 127mm x 30mm (3.2” x 5.0” x 1
Weight (approx.)	200g (6.6oz)
Channel Bandwidth (A, B)	0Hz – 40Hz
Channel Bandwidth (C, D, E, F, G, H)	0Hz – 5Hz
Sample Rate/Channel (A, B)	20 - 256 samples/second
Sample Rate/Channel (C, D, E, F, G, H)	20 - 256 samples/second
Supply Voltage	3.0V – 6.5V
Low Battery Warning	3.2V ±0.2V
Current Consumption	40mA – 80mA @ 6.0V
Accuracy	±5%
Data Output Protocol	19.2 Kbaud, 8 Bits, 1 Stop, No Parity
Battery Life (Alkaline)	18 to 20 Hours (minimum)

Skin Conductance Flex/Pro Sensor (SA9309M)

Size without electrode leads (approx.)	3.5 cm (1.4")
Size with electrode leads (approx.)	15 cm (6.0")
Cable Length (approx.)	127 cm (50")
Weight (approx.)	25 g (1 oz)
Signal Input Range	0 – 30.0 µS
Accuracy	±5% and ±0.2 µS

HR/BVP Flex/Pro Sensor (SA9308M)

Size (Approx.)	20mm x 34mm x 10mm (0.72" x 1.33" x 0.41")
Weigh	20g (0.66 oz)
Input Range	Unitless quantity displayed as 0% – 100%
Accuracy	±5%

Temperature Sensor (SA9310M)

Length (Approx.)	152cm (60")
Weight	10g (0.33 oz)
Temperature Range	10°C – 45°C (50°F – 115°F)
Accuracy	±1.0°C (±1.8°F) 20°C – 40°C (68°F – 04°F)

MyoScan Pro EMG/EKG Sensor (SA9401M)

Size (Approx.)	37mm x 37mm x 15mm (1.45" x 1.45" x 0.60"
Weight	25g (1 oz)
Input Impedance	1,000,000MΩ in parallel with 10pF
Input Range	0 – 400µV, 0 – 1600µV
Sensitivity	<0.1μV_{RMS}
Bandwidth	20Hz – 500Hz
Accuracy	±5%, ±0.3µV

Canon VRC25 Video Camera:

Television system	EIA standard (525 lines,60 fields) NTSC color signal
Video recording system	2 rotary heads, helical scanning system DV system (Consumer digital VCR SD system) Digital component recording
Television system	EIA standard (525 lines,60 fields) NTSC color signal
Video recording system	2 rotary heads, helical scanning system DV system (Consumer digital VCR SD system) Digital component recording

BIBLIOGRAPHY

Blatz W.E., "The Cardiac, Respiratory and Electrical Phenomena involved in the Emotion of Fear," *Journal of Experimental Psychology*, 1968

Brodsky P. and Bordsky M., "An Arousal Interval Scale: A Psychophysical Scale for GSR Analysis," *Perceptual and Motor Skills*, 47, 1978.

Freeman J., Avons S.E., Pearson D.E., and Ijsselsteijn W.A., "Hear, There and Everywhere, The Effects of Multichannel Audio on Presence," paper presented at the proceedings of the 2001 International Conference on Auditory Display, Espoo, Finland, August 2001.

Jorna, P.G., "Spectral analysis of heart rate and psychological state: A review of its validity as a workload index," *Biological Psychology,* 34, pp. 237-257, 1992.

Mulder, L.J., "Measurement and analysis methods of heart rate and respiration for use in applied environments," *Biological Psychology,* 34, pp. 205-236, 1992.

Plutchik, R., "The Effect of High Intensity Intermittent Sound on Performance, Feeling and Physiology," Psychological Bulletin 56(2), 1959.

Porges, S.W., Byrne, E.A., "Research methods for measurement of heart rate and respiration," *Biological Psychology,* 34, pp. 93-130, 1992.

Prothero J.D., Parker D.E., Furness T.A., Wells, M.J., "Towards a Robust, Quantitative Measure for Presence," in Proceedings of Conference on Experimental Analysis and Measurement of Situational Awareness, pp. 359-366, 1995.

Schaefer F., Boucsein W., "Comparison of Electrodermal Constant Voltage and Constant Current Recording Techniques Using the Phase Angle Between Alternating Voltage and Current," *Psychophysiology*, 37, 2000.

Singer, M.J., Witmer, B.G., “On Selecting the Right Yardstick,” Presence: Teleoperators and Virtual Environments, 8(5), 1999.

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